Nature Conservation Management of Tropical and Sub-Tropical Island Territories

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Abstract

Within the Island Territories of the Commonwealth, the nature conservation values of Christmas Island, North Keeling Island, the Ashmore Islands, Norfolk and Philip Islands and the Coral Sea Islands of the Coringa Herald and Lihou Reef National Nature Reserves are considered in tabular form. This paper describes their principal terrestrial biological values and the main historical and current impacts upon those values. The conservation management of the islands is described including the establishment of parks and reserves, recent biological surveys, feral animal and noxious weed control, education and law enforcement. The brief case studies of specific island management techniques are presented. Results of the first eighteen months observations from the Abbott's Booby Monitoring Program are assessed in the light of management of the species on Christmas Island. The techniques and results of an extended rabbit program on Philip Island in the South Pacific are described and assessed.

INTRODUCTION

The Australian National Parks and Wildlife Service (ANPWS) is the principal adviser to the Commonwealth Government on national nature conservation and wildlife policies. It works in close co-operation with other Commonwealth Authorities and with relevant State and Territory Agencies. Two of the identified functions of ANPWS, which have particular relevance to oceanic islands, are:

> providing an advisory service to the Department of Territories with respect to the management of wildlife, parks and reserves in external territories;
>
> managing parks and reserves in external territories according to approved guidelines with regard to the local situation.

This paper outlines recent ANPWS involvement in nature conservation management of islands in the tropical or sub-tropical Territories of Christmas Island, Norfolk Island, Ashmore and Cartier Islands, Coral Sea Islands and Cocos (Keeling) Islands (Fig. 1). A description of the islands, their conservation issues and recent conservation management are presented in tabular form. Two island case studies of particular interest are then described. In the first, the Abbott's Booby monitoring program on Christmas Island, the susceptibility of this endangered seabird to habitat disturbance is described along with management implications arising. The second case study on feral species eradication on Philip Island, is a dramatic case study of how severe damage by rabbits on an island ecosystem can be halted.

Case Study - Monitoring

MONITORING AND MANAGEMENT OF ABBOTT'S BOOBY, CHRISTMAS ISLAND, INDIAN OCEAN

Introduction

Abbott's Booby (*Sula abbotti*) is one of the few seabirds unique to Australia or its territories. Though once widely distributed in the Indian Ocean, the species now nests only on Christmas Island (10°14'S, 42'E), probably because of destruction of nesting habitat at previous breeding stations. The current breeding population is estimated at 2 000 pairs of which about half attempt to breed each year.

Clearing of forest on Christmas Island for phosphate mining has raised concern for the survival of the species. It is listed in Appendix 1 to CITES and in the Schedule to the Australia-Japan Migratory Birds Agreement.

The first major study of the bird's breeding biology was by Dr J.B. Nelson in 1967 (Nelson 1971) shortly before extensive forest clearing commenced in the central and western parts of the Island which were preferred Abbott's Booby habitat. Concern over

1. Territory of Cocos(Keeling) Islands
2. Territory of Christmas Island
3. Territory of Ashmore and Cartier Islands
4. Coral Sea Islands Territory: Islands only
   4a. Coringa-Herald National Nature Reserve
   4b. Lihou Reef National Nature Reserve
5. Territory of Norfolk Island

Figure 1. Location of tropical and sub-tropical island territories

Appendix 1

Island territories - summary of natural features, impacts and conservation management

CHRISTMAS ISLAND (10°S, 106°E An elevated atoll of 13 500 ha covered with rainforest that has been cleared in places for phosphate mining.

Significant Natural Features	Main Impacts	Conservation Management
Spectacular coastal and inland cliffs. Unusually structured primary rainforest. Unique stand of mangroves (Bruguiera) perched 30m above sea level. Major colonies of seabirds including the endangered Abbott's Booby Sula abbotti and Christmas Island Frigatebird Fregata andrewsi. Spectacularly high populations of landcrabs. Endemic species and subspecies (21 plants, 5 reptiles, 2 bats, 1 shrew, 10 birds and 2 landcrabs).	(a) Habitat destruction 22% of Island vegetation has been cleared for phosphate mining and associated purposes. (b) Introduced plants False Acacia Leuceana glauca, Sensitive Plant Mimosa invisa and Japanese Cherry Muntingia calabura are major weeds of disturbed areas but have not spread into intact rainforest. (c) Introduced animals Introduction of four cosmopolitan rodent species blamed for the apparent extinction of 2 endemic rats. Domestic cats and dogs disturb ground nesting seabirds near settlement. Some feral cats may affect landbirds. Feral honey bees occur. Giant African Snails Achetina fulica are common in disturbed areas but do not venture into intact rainforest. (d) Hunting Hunting of Robber Crabs Birgus latro and Fruit Bats Pteropus natalis is permitted outside the National Park. Poaching of Blue Crabs Cardisoma hirtipes, Imperial Pigeons Ducula whartoni and seabirds occurs.	(a) Land-use planning/park declaration 12% of Island declared as National Park in 1980 following an environmental study in 1976. A further 5% currently proposed for declaration. A plan for the Park has been prepared (ANPWS, 1985). Conservation priorities for all Island areas have recently been assessed and considered in a land-use study commissioned by Department of Territories. Guidelines to minimise the impact of forest clearing for mining have been adopted and future clearing for mining will be limited to less than 3.3% of the Island. Conservation staff supervise implementation of guidelines. (b) Conservation staff Resident Government Conservator (since 1977) and assistant (since 1984). Three resident scientists working on Abbott's Booby Monitoring Program. (c) Recent biological surveys ANPWS consultants have studied the status of the Island's Imperial Pigeon (Crome, 1978), bats (Tidemann, 1985), terrace seabirds (Woehler, 1984) and landcrabs (George, 1978) and the distribution of plant communities (Mitchell, 1985). A habitat survey of Abbott's Booby (Powell and Tranter 1980) has been followed by a comprehensive monitoring program on Abbott's Booby breeding success (Reville et al., 1984 and 1985). The distribution, abundance and nest site preferences of the Christmas Island Frigatebird have been identified, using three years of comparative data and collection of breeding success data has commenced (Stokes, unpublished data). A comparative breeding study of the White tailed Tropicbird (endemic sub species) and Red-tailed Tropicbird commenced in 1983 (Stokes unpublished. data). (d) Feral animal control Since 1982 stray cats and dogs around the settled areas have been controlled. Robber Crabs Birgus latro have been observed predating African Land Snails. (e) Weed Control Where weeds interfere with regeneration of mined out areas, some control activities are undertaken by the Phosphate Mining Company of Christmas Island. The weeds do not penetrate intact rainforest. (f) Education and enforcement Resident Conservator vets applications for importation of plants and animals. Regular patrols undertaken to control poaching. Since 1980 environmental education program has been underway using publications, displays and ranger guided activities. A vigourous natural history association is present. (g) Other environmental matters The Government Conservator is the administration adviser on all environmental matters affecting the island eg pollution, litter, pests and pesticides, customs/quarantine regulations and activities.

NORFOLK ISLAND AND PHILIP ISLAND (29°S 168°E), Norfolk Island covers 3 500 ha and Philip Island 250 ha. Both are emergent volcanic outcrops. Norfolk Island is mixed farm land, urban and natural and introduced vegetation. Philip Island is heavily eroded and in the process of revegetation with native and introduced species.

Significant Natural Features	Main Impacts	Conservation Management
50 plant species are endemic to Norfolk, 10 of these are endangered or extinct. 13 endemic species or sub-species of landbird of which 5, possibly 6 are extinct. 11 seabird species regular breed on the island.	(a) Habitat destruction. Philip Island vegetation communities have been almost completely destroyed by introduced rabbits. Most of the rainforest on Norfolk has been cleared for settlement and grazing. Habitat destruction contributed to the extinction of the Norfolk Island Starling Aplonis fuscus fuscus and Black and White Sparrow Lalage leucopyga. (b) Introduced plants. Weeds occur throughout most of the remaining rainforest (ANPWS, 1984). The most troublesome are Red Guava Psidium littorale, Hawaiian Holly Hinus terbinthifolius, and African Olive Olea africana. Other weeds important in smaller areas include Lantana comara, William Taylor Eupatorium riparium, Wild Tobacco Solanum mauritianum and Kikuyu grass. (c) Introduced fauna. On Norfolk Island Black Rats Rattus rattus, Kiore Rattus exulans and Feral cats Felis catus seriously affect populations of land and seabirds (ANPWS, 1984). On Norfolk Island domestic cattle have affected the rainforest by browsing on seedlings and trampling. Ten introduced bird species are present including the European blackbird Turdus merula, European starling Sturnus vulgaris, Silvereye Zosterops lateralis and Crimson Rosella Platycercus elegans which have contributed to the extinction /decline of the endemic Grey-headed Blackbird Turdus poliocephalus, Norfolk Island Starling Aplonis fuscus fuscus, White-breasted White Eye Xosterops albogularis and Green Parrot Cyanoramphus novaezelandiae cookii. (d) Hunting. The Norfolk Island Dove Columba sp. and Pigeon Hemiphaga novaeseelandiae argetraea and the Providence Petrel Pterodrama solandri were believed exterminated mainly by hunting (Fullagar, unpublished). Since 1985 attempts at breeding by the Providence Petrel on Philip Island have been observed.	(a) Land use planning declaration. 13% of Norfolk is currently declared as National Park. A plan for the Park has been prepared (ANPWS, 1984). (b) Conservation staff. Resident Conservator (since 1978) with assistant (since 1981) and an administrative assistant (since 1984). (c) Biological surveys. ANPWS consultants have studied the terrestrial invertebrate fauna on Philip Island (Taylor, unpublished), weed species in the National Park (Haseler, 1985), and lichens and mosses (Elix 1985). ANPWS staff have carried out studies of the population of Sooty Terns on Philip Island (Hermes, unpublished), the status of the Norfolk Island Owl and Scarlet Robin and the status of the Norfolk Island Green Parrot Cyanoramphus novaezelandiae cookii (Forshaw 1979). (d) Feral animal control. Major program to eradicate rabbits from Philip Island completed May 1988. (e) Weed control. One small plantation of Hoop Pine Araucaria cunninghamii was removed because fears were expressed that its presence could jeopardise genetic integrity of the closely related endemic Norfolk Island Pine Araucaria heterophylla. Weed control is one of the major management activities in the National Park. (f) Education and enforcement. Since 1979, an environmental education program has been underway using displays, ranger-guided activities and publications including contributions to local newspapers. (g) Captive breeding program. In an endeavour to prevent the extinction of the Norfolk Island Green Parrot, birds are currently held in captivity in an endeavour to captive breed the sub species. Captures indicate a predominance of males in the remaining population.

ASHMORE ISLANDS (12°S 123°E EAST ISLAND 16ha, MIDDLE ISLAND 13ha, WEST ISLAND 32ha. The three islands are herb and grass covered cays with fringing shrubs on Middle and West Islands.

Significant Natural Features	Main Impacts	Conservation Management
Breeding colonies of 15 seabird species including the second largest reported Australian colony of Bridled Terns Sterna anaethetus, the largest reported Australian colony of Noddies Anous stolidus, one of only three known Australian colonies of the White-tailed Tropicbird Phaethon lepturus, a large colony of Sooty terns Sterna fuscata, and the only known breeding colony of what is thought to be a new species of tern. Moderate numbers of Green Turtles Chelonia mydas and some Hawksbill turtles Eretmochelys imbricata nest on West Island and, to a lesser extent, Middle Island. The surrounding lagoon and reef support a rich and diverse marine life with a high degree of endemism and possibly the greatest abundance and diversity of species of sea snakes in the world.	(a) Habitat destruction. Guano extractors reportedly worked the Ashmore Islands in the later part of the 19th century (Woodward, 1917). The depauperate herb and grass growth in the interior of West Island (compared to East and Middle Islands) suggest that mining only occurred on West Island. Recent lopping of fringing shrubs by Indonesian fishermen for firewood and for construction of fish drying racks has been observed. (b) Introduced plants. Although a number of plants such as the Coconut palm Cocos nucifera and maize Zea mays have been introduced, none have spread. (c) Introduced fauna. Rats Rattus rattus have been recorded in large numbers on West Island since 1949 (Serventy, 1952) and mice have more recently been recorded on Middle and East Islands. Rats may be implicated in the absence of attempts at breeding on West Island by smaller seabirds and the limited breeding success of Crested Terns Sterna bergii in 1984. (d) Hunting. Indonesian fishermen have frequently taken seabirds, turtles and both seabird and turtle eggs in contravention of a Memorandum of Understanding with Indonesia concerning permitted activities of Indonesian fishermen in the area. The failure of the larger seabirds Sula leucogaster and Fregata ariel to breed successfully on the Islands till 1988 is attributed to poaching and disturbance. Damage to vegetation by fishermen for firewood, drying racks and camping materials has been substantial.	(a) Park declaration. The Ashmore Reef National Nature Reserve, which encompasses the Islands and 583 km2 of surrounding reefs and waters was declared in 1983. A plan of management is being prepared. (b) Conservation staff. Mainland based ANPWS officers conduct regular patrols of the islands in association with the Civil Coastal Surveillance Program on RAN patrol boats. In 1984/85 there were 17 such patrols. (c) Recent biological surveys. Data on seabirds, vegetation and human use are collected routinely on surface patrols. (d) Feral animal control. A rat eradication program was undertaken in 1984/85 and appears to have been successful. Technique used was Bromadiolone in the form of Bromakil wax blocks; dispensed in PVC spouts imbedded in the soil at 40 m grid square with raised entrances at 45° to deter non target (Hermit Crab Coenobita perlata consumption. Poison stations rebaited at 2-3 week intervals. Warfarin (Ratsak) also employed to treat persistent populations. (e) Weed control. None necessary. (f) Education and enforcement. a program informing and warning Indonesian fishermen using the area is in place. In 1984/85, ANPWS wardens boarded 59 Indonesian fishing vessels under the program. Recently the Department of Territories stationed two personnel on West Island, to inform Indonesian fishermen of constraints in use of the area. Distance from nearest Australian port (450 km) has prevented arrest of offenders due to relative fragility and slow speed of traditional craft. (g) International agreement. The Government proposes to renegotiate the agreement under which Indonesian traditional fishermen have been allowed physical access to the Islands.

CORAL SEA ISLANDS IN CORINGA HERALD AND LIHOU REEF NATIONAL NATURE RESERVES (NNR) between 16 to 18°S and 149 to 152°E. Six islands in Herald Coringa NNR have total area of 125 ha and 16 in Lihou Reef NNR have a total area of 91 ha. The Islands are all cays; vegetation cover varies from nil (13 cays), grassland/herbland (9 cays), fringing shrubland (5 cays) and closed Pisonia forest (3 cays).

Significant Natural Features	Main Impacts	Conservation Management
Nesting areas for 13 seabird species including the most important Australian breeding grounds (after Christmas Island and North Keeling) for the Red-footed Booby Sula sula and Great Frigatebird Fregata minor (Hicks, 1985). The most highly developed vegetation communities on islands in the Coral Sea, including closed Pisonia forest on 3 islands. Green Turtles nest on the cays in large numbers.	(a) Habitat destruction. The vegetation of Chilcott Island may have been affected by guano extraction last century although signs of such damage are not obvious. Otherwise natural habitats intact (Hicks, 1985). (b) Introduced plants. No significant weeds. (c) Introduced fauna. Black rats (Rattus rattus) are present on Coringa Islet and may adversely affect bird populations there (Hicks, 1985). (d) Hunting. No recent hunting pressures.	(a) Park declaration. Reserves declared in 1982. (b) Conservation staff. No resident staff. Regular patrols by ANPWS staff conducted in association with Civil Coastal Surveillance Program on RAN patrol boats. (c) Recent biological surveys. Data on seabirds, vegetation and rats has been obtained during voyages on lighthouse tender vessels (Hill, 1984), during naval patrols and during a month long joint Australian Survey Office. ANPWS survey in 1984 (Hicks, 1985). (d) Feral animal control. Rat control measures on Coringa Islet commenced in 1985. (e) Weed control. None necessary. (f) Education and enforcement. Surface patrols monitor human use of the cays.

NORTH KEELING ISLAND 12°S, 97°E. An atoll of 140 ha covered mostly with *Pamphis* scrub fringing the lagoon.

Significant Natural Features	Main Impacts	Conservation Management
North Keeling is the only island of the Cocos-Keeling group with intact natural vegetation communities. Closed Pisonia forest covers much of the Island (Hicks, 1985). It is one of the few remaining pristine islands in the Indian Ocean (Stokes et al. 1982). Major breeding populations of Red-footed Boobies Sula sula, Least Frigatebird Frigata ariel, Great Frigatebird Fregata minor, White Tern Gygis alba, Common Noddy Anous stolidus and small breeding colonies of 6 other seabirds including two species tropicbird (Stokes, et al. 1982). The only remaining significant breeding colony of the endemic Cocos Buffbanded Rail Rallus philippensis andrewsi. High population of landcrabs Cardisoma hirtipes and a moderate population of the vulnerable Robber Crab Birgus latro.	(a) Habitat destruction. Much original forest remains intact, unlike islands on the main Cocos Atoll where coconut plantations have largely replaced it (Stokes et al., 1982). (b) Introduced plants. Not known to be a problem. (c) Introduced fauna. No rats or cats on North Keeling whereas both are common on islands of the main Cocos Atoll. (d) Hunting. Hunting and other human disturbance drove the majority of seabirds away from the main atoll by 1985 (Forbes, 1885; Fibson-Hill, 1949). Hunting of seabirds on North Keeling, a long established custom by cocos Malays, is thought to have increased in recent years (Stokes et al, 1982). The harvest in 1985 was estimated at 6 000-10 000 birds, mainly immature Red-footed Booby from a population estimated at 17 000 + breeding pairs (Hicks 1985). This is thought to be similar to the hunting pressure taking place since 1982. Prior to that data limited historical data indicates from 3 000-10 000 birds per annum were taken intermittently over the previous 70 years.	(a) Park declaration/Land use. The Island and most of the land on the main atoll were transferred to the Cocos (Keeling) Islands Council in 1984. Transfer of North Keeling was conditional on the acknowledgement of the special need to protect the environment of North Keeling and the early introduction of conservation measures and a management plan for the Island (Anon, 1984). (b) Conservation staff. ANPWS officers, at the request of the Department of Territories, visited the Island three times in 1985 to assist in seabird conservation measures. It is expected that one ANPWS officer will be allocated to work full-time on Cocos conservation matters in the near future. (c) Recent biological surveys. Stokes et al. (1982) described the birds on the Island. Hicks (1985), has collected seabird population and breeding success data for Sula sula and Fregata ariel, the main species harvested. Information has also been collected on historical harvesting levels. The flora has recently been studied by Telford (1985, unpublished). (d) Feral animal and weed control. None necessary at present. (e) Education and enforcement. The Cocos Malays with a population of 376, have had little exposure to wildlife conservation practices and have a long tradition of taking seabirds and other wildlife produce for food. Seabird flesh is particularly favoured for traditional festivities. An environmental education program, which focuses initially on seabird management, has been commenced during visits by ANPWS officers.

the effects of this clearing prompted an island-wide survey of the distribution of nesting sites in 1979/80 conducted by the Conservation Officer for the British Phosphate Commissioners and the Assistant Government Conservator (Powell and Tranter 1981). Following an appraisal of this report and recommendations to the Federal Government a program to monitor the bird's breeding success was established in July 1983, staffed by three ANPWS officers and jointly funded by ANPWS and the Phosphate Mining Company of Christmas Island.

The current Monitoring Program was established with the aim: "to monitor the breeding success of Abbott's Booby to permit continual review of the protection of the bird and the continuation of mining." The results of the program are reviewed annually by an expert panel comprising Dr J.B. Nelson of Aberdeen University, Professor J.M. Cullen of Monash University, the Director, ANPWS, the General Manager PMCI and the head of the monitoring team, Dr B. Reville.

Methodology

The chief technical difficulty in designing a research program to achieve this has been the extreme inaccessibility of the birds: nests are typically placed on thin lateral branches about 30 m above the ground. Also, the nests are scattered over some 10 sq km in different relations to forest clearings and in a wide variety of topographic situations.

The methodology adopted gathers information at two levels, very detailed information at a few sites through time-lapse photography and less detailed information from fortnightly checks on about 600 sites selected at random from the distribution mapped in 1979/80. A wide variety of physical characteristics for each of these sites has been recorded including tree diameter, tree height, position of nest in canopy, branch diameter, branch number, branch angle, slope of ground, topography, distance from clearing, number of adjacent clearings, size of clearing, tree aspects, aspect to clearing and compass bearing of nest in tree.

Monitoring Results

By the end of 1983 it was clear that:

the birds nested only in tall rainforest trees, especially (70%) in *Planchonella nitida* and *Eugenia grandis*;

nests were restricted to the western half of the island, mostly in rugged topography sheltered from the prevailing South-East Tradewinds;

productivity was extremely low since only one egg was laid per clutch and successful pairs usually laid in only every second year;

typically, the birds were faithful to mate and nesting site from year to year, hence destruction of the nesting tree was likely to be detrimental to subsequent breeding success.

Based on information from two complete seasons, 1983/84 and 1984/85, the results indicate:

1. breeding success (egg to independence) was significantly affected by date of laying, with late laying resulting in lower breeding success;
2. breeding success in 1984/85 (24%) was significantly lower than in 1983/84 (46%), probably due to food shortage;
3. breeding at more frequent intervals than every second year did not contribute significantly to population recruitment;
4. in 1983/84 there was a significant decline in nesting success (independent young/nest) with increasing nest density;
5. in both seasons, nesting success improved with increase in number of branches supporting the nest, suggesting that nest stability is an important factor in breeding success;
6. in 1983/84, the presence of forest clearing to the South-East within 762 m of nest sites significantly diminished their nesting success, especially if the aspect of the tree containing the nest was also South-East; this effect was exacerbated by increase in number and size of clearings;
7. areas within 305 m of clearings have displayed a higher rate of nest site abandonment and have attracted proportionately fewer nests since 1979/80 than areas further away from clearings - these trends appear to be continuing;
8. annual site reoccupation since 1979/80 has been c. 96-98% beyond 762 m of clearings and c. 86% within 305 m of clearings;
9. birds occupying new sites had lower breeding success than birds in familiar sites;
10. in addition, the higher rate of abandonment of nesting sites near clearings suggests that the carrying capacity of habitat within 305 m, and perhaps 762 m of clearings has been significantly reduced. Only about 12% of known nesting habitat of Abbott's Booby remains beyond 762 m of existing clearings;

11. on average, nests which lie within 305 m and to the North-West of areas cleared in the early 1970's are still experiencing diminished nesting success approximately 16% (30 cf. 46%) lower than the rest of the population. Since 37% of nests lie within this zone a substantial proportion of the population has been experiencing reduced nesting success for up to fifteen years.

Discussion

These findings raise serious concern for the survival of Abbott's Booby since it seems that forest clearing may set in train a long-lasting sequence of detrimental effects through increasing exposure of the forest canopy to the prevailing South-East Tradewinds.

Abbott's Booby fulfils the classic recipe for an endangered species - slow breeding, specialised habitat preferences and sensitivity to human disturbance.

The Abbott's Booby Monitoring Program Expert Panel considers that the implications for management of these results are threefold:

> areas of intact forest are likely to have higher long-term carrying capacity than the margins of existing clearings, thus clearing of hitherto intact forest should be avoided;
>
> further clearing of forest within 305 m and to the South-East of significant numbers of Abbott's Boobies should not occur;
>
> existing clearings to the South-East of significant numbers of Abbott's Boobies should have priority in rehabilitation programmes.

The first of these implications has already been acknowledged in decisions regarding further clearing for mining, allowing access to valuable ore bodies beneath habitat now recognised as already deteriorating, while removing areas of intact forest from the current mining schedule.

It is hoped that the remaining implications will be acknowledged in determining future priorities in land-use, particularly in the preservation of suitable areas of intact forest to ensure the survival of Abbott's Booby and determining which existing clearings are to be developed for agricultural and pastoral purposes and which are to be revegetated to ameliorate adverse effects on existing Abbott's habitat.

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Case Study - Eradication

RABBIT ERADICATION PROGRAM - PHILIP ISLAND, SOUTH PACIFIC

Introduction

Few places have suffered more than Philip Island from human mismanagement though it has never been permanently inhabited by man (Fullager 1978, Coyne 1981 and 1982). The island of about 240 ha is about 6 km South of Norfolk Island in the south-west Pacific Ocean. When discovered in 1774 it supported a dense subtropical forest. Pigs were released on Philip Island in about 1790 followed by goats and rabbits. These animals rapidly destroyed much of the vegetation and severe soil erosion began. By about 1870 the pigs and goats had gone but the rabbits remained preventing any substantial revegetation and allowing continuous and severe erosion to create a spectacular, barren landscape. Of volcanic origin much of the island appears to have lost approximately one metre of soil. The rabbits by the 1970's were predominantly brown and black in colour unlike the agoutis of Australia and show little tendency to burrow for shelter.

In 1979 the Norfolk Island Council asked the Australian National Parks and Wildlife Service to undertake an experimental program to investigate the damage caused by rabbits and the potential for re-establishing vegetation. Exclosures soon provided spectacular evidence of the effect of rabbit grazing and the ability of the 'soil' to support plant growth. Protection from grazing allowed otherwise unassisted regeneration of both native and introduced species in amazing quantities. Some previously bare sites were quite densely vegetated within six months of fencing, supporting up to 22 plant species, while outside the fences the ground remained bare. By 1980 results of the experimental program has been so spectacular that the Norfolk Island Legislative Assembly asked the Australian National Parks and Wildlife Service to eradicate rabbits from Philip Island.

Methods

Philip Island presented special difficulties for implementing a rabbit eradication program. The extremely rugged terrain, with many colonies on nearly inaccessible slopes, the unreliability of transport to and from the island due to unpredictable seas and the logistical difficulties in having to carry all supplies around the island in backpacks prevented the application of conventional rabbit control techniques. After consultation with CSIRO, it was decided to use

myxomatosis in conjunction with the European rabbit flea.

In March 1981 disease free European rabbit fleas were released on captured rabbits and in burrows in order to establish fleas in the population for future use as vectors for myxoma virus.

Introduction of myxoma began in August 1981 with some rabbits being inoculated subcutaneously or infected ;with eye paste and released but the principle technique was to release rabbit fleas which carried virus particles. To ensure full cover of fleas on the island necessitated staff climbing into some otherwise inaccessible sites and swimming into others. However some populations still remained inaccessible and a rather primitive but effective method of delivering the fleas was developed.

Fleas in a small glass phial were attached to the steel head of an arrow which was shot from a longbow. This method relied upon the momentum of the arrow shattering the phial on impact with the ground thus releasing the fleas.

It was possible to deliver fleas on horizontal ground 90 m away in this manner. In conjunction with a 265 m fall delivery was estimated to extend to 200 m.

By December 1981 all areas of the island had been treated, the rabbit population had declined and vegetation increased remarkably. However the rabbit population stabilised at previous late summer levels. A prefabricated hut was constructed on the island in March 1982 to facilitate the program and improve living conditions for personnel isolated by sea conditions.

In July 1982 a stepped-up myxoma release program was successful in again reducing the rabbit population. In this program greater emphasis was placed on inoculating live rabbits caught in wire funnel traps planted with rye corn or baited with carrot, pigface *Carpobrotus* or oats.

The attraction of exclosure plots containing regenerating vegetation was exploited by either setting perimeter traps or converting some partially or wholly to funnel traps to capture animals for inoculation or flea release. By December 1982 the supply of rabbit fleas all but stopped. Rabbit numbers had not by that stage been reduced sufficiently to enable isolation of small groups which could be treated separately. Curtailment of supplies of rabbit fleas necessitated a change of technique before rabbit numbers again built up. During the winter and spring of 1983 a major build up of supplies on the island was conducted in preparation for poisoning with 1080 'one shot oats'. Oats were used as free-feed in 320 dispensers for several months and in November 1983 poisoning began. The first poisoning reduced the population dramatically, perhaps as much as 90%. A month later the bulk of the island was poisoned again and after this about 12 discrete areas of known rabbit activity remained. Oats continued to be used as the principal bait with carrot and pigface used to a lesser extent. To treat cliff ledges and slopes disposable plastic food containers of 1080 treated chopped carrots were hurled from above and exploded on impact spreading the baits.

After initial poisoning to dramatically reduce numbers other techniques were introduced as appropriate to each population's special conditions. Techniques used included trapping, gassing, shooting, habitat removal by burning, hand ripping and barrier fencing. No one technique was 100% effective in any one area and depending on conditions different techniques were more or less useful. Funnel traps were in some instances built into barrier fences to intercept animals attempting to enter clean areas. Shooting was only useful once the population had been otherwise reduced. A .22 rifle equipped with silencer was used for sniping animals at close range; a .222 high powered rifle equipped with a 8 power x 56 scope was used for long distance shooting on the cliffs where wind turbulence was a consideration.

From January 1984 to November 1985 work concentrated on removing each of the discrete groups. On occasion reinfestations of previously cleared areas were detected. By June 1985 all populations capable of colonising other areas had been eliminated and at that time 6 discrete groups remained on ledges and slopes isolated by cliffs and barrier fences. By November 1985 only 2 groups remained.

For staff to land on these last two sites required vertical rock climbs/descents of at least 180 m or landings from the sea on dangerous rocky shores. Destruction of these last rabbits was planned when sea and weather conditions allow access by zodiac inflatable craft during the summer of 1985/86.

Discussion

As normal field strains of the myxoma virus are of moderate virulence, they could not be expected to kill all rabbits infected, although in a previously unexposed population such as Philip Island, mortality could be expected to be as high as 99.5% of infected rabbits. A highly virulent artificially bred strain (Lausanne Strain) was chosen for use on Philip Island because no rabbits were likely to recover and hence become resistant. However rabbits infected with this strain die faster than would be the case with a less

virulent strain and the Lausanne Strain was therefore expected to be less transmissible than field strains. In the event progress using a combination of methods had not proved successful an option remaining would have been to introduce a persistent field strain to achieve a high degree of control.

The lack of total success with the myxoma release program was due to inadequate numbers of vector insects and the failure of the fleas to successfully breed. This led to poor transmissibility and repeated extinction of the virus. Rabbit numbers were never reduced sufficiently by myxomatosis to enable isolation of small groups of rabbits which could be treated separately.

The apparent lessons learnt by this program were that reliance should not be placed on any single control mechanism. Myxoma virus was effective in reducing rabbit numbers to the extent that the subsequent use of oats and 1080 was logistically feasible. Techniques were applied sequentially so as to ensure that the survivors of one technique were naive to the next eradication method.

The last rabbit killed on the accessible main body of the island was observed evading two types of trap before being shot. A large black male, it was found to be carrying an eartag indicating it had previously been live trapped and inoculated with Lausanne Myxoma virus indicating recovery or ineffective inoculation.

Predatory animals were not employed because of the significant populations of breeding seabirds on the island. Staff were required to develop a keen eye for rabbit signs in order to detect active areas as well as develop hitherto unknown climbing abilities. Unconventional climbing techniques developed included the use of star pickets as belay points on the crumbling volcanic soils.

The significant removal of the rabbits by January 1983 and effective eradication from the bulk of the island by June 1985 has allowed vigourous plant growth. The changes are being monitored by photo points, vegetation surveys and aerial photography.

A species of plant *Abutilon julianae* endemic to the Norfolk Island group and presumed extinct since the beginning of this century was recently found on Philip Island.

POSTSCRIPT

The last two sites received one poisoning each followed up by shooting and trapping. By May 1986 both areas and the remainder of Philip Island were believed clear. Periodic monitoring continued however and in January 1988 a rabbit was sighted on a cliff ledge in an area believed cleared in February 1986. A descent was made in February 1988 but the inaccessibility of the ledge prevented the use of direct methods. What is believed to have been the last rabbit on Philip Island was eventually shot from the adjacent cliffs on 25 February 1988.

In the course of this program a small population of Providence Petrel *Pterodroma solandri* were discovered breeding on the higher parts of Philip Island. Once numerous on Norfolk Island this species was considered locally absent for almost 200 years. Its only other known breeding site is Lord Howe Island.

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