Assessment of the weed control programme on Raoul Island, Kermadec Group

SCIENCE & RESEARCH SERIES NO.98

Carol J. West
Department of Conservation
P O Box 743
Invercargill

Published by
Department of Conservation
P.O. Box 10-420
Wellington, New Zealand

Science & Research Series is a fully reviewed irregular monograph series reporting the investigations conducted by DoC staff.

ISSN 0113-3713
ISBN 0-478-01801-0

Cataloguing in Publication
West, Carol J. (Carol Joy), 1957-
Assessment of the weed control programme on Raoul Island, Kermadec group / Carol J. West. Wellington, N.Z. : Dept. of Conservation, 1996.
1 v. ; 30 cm. (Science & Research series, 0113-3713 ; no. 98.)
Includes bibliographical references.
ISBN 0478018010
1. Weeds--Control--New Zealand- -Raoul Island. 2. Raoul Island (N.Z.) I. Title. II. Series: Science & research series ; no. 98.
632.58099399 20
zbn96-035473

CONTENTS

Abstract

The weed eradication programme on Raoul Island has been running for 20 years and has been regularly reviewed during that time. The number of hours expended on weed eradication has varied from year to year, as circumstances dictated. Over the years the focus has shifted from heavy reliance on the use of chemicals (and fire) to control dense infestations of species to the current situation where most time is spent searching for individual plants (or groups) of the target species and physical destruction of those. The exotic plant species have been listed in different categories for action, and in this assessment the categories have been reduced to three only. Category A species are to be eradicated and are subdivided into two groups in which the reason for eradication is different. Categories B and C comprise the rest of the exotic flora and are currently not targetted for eradication, although some have been in the past, and some may be in the future. The latter category contains introduced species which have historic significance and the former contains the balance of the flora. Active control of a few of these species is recommended. Thirteen species are listed and discussed in Category A(i), four in A(ii), seven in B and eight in C. The remainder of species in categories B and C are listed in Appendices 2 and 3, with brief notes. For each of the species in the body of the text, their history on the Island, ecology, control methods and future work requirements are described. Documentation of these details enables a clear understanding of how much progress has been made already, what the characteristics of the different species are, how much more there is to do, and how that will be achieved, given current knowledge and technology.

Although only one species can be clearly identified as having been eradicated in 20 years of operation, the level of reduction of category. A species in that time is substantial. Every dead plant is one less contributing to future generations. Many of the species have a persistent seed bank and this inevitably prolongs the eradication programme for an unknown period of time. At this stage of the programme, any individual which contributes seed to the seed bank pushes the conclusion of the programme further into the future. Thus, the primary goal of the programme is to prevent this happening, by finding and destroying all individuals before they set seed.

1. Introduction

The presence of exotic species on Raoul Island has been the subject of interest or concern for many decades now. Perhaps the first comment on the intrusion of exotic plants into the natural communities of Raoul Island was made by Guthrie-Smith (1936) who stated ". . . lovely as is the island in its half tropical luxuriance, its charm nevertheless is deprecated to the naturalist by the presence of goats and pigs and by the settlement at different periods of several different families, each of whom has dragged in its wake unwanted weeds; it grated on our feelings to note, for instance, the ngaio woods at Western Bay [Denham Bay] carpeted with our garden ageratum . . ."

When Sorensen was stationed on the Island for seven months in 1944 he investigated natural history and, although his focus was on animal species, he devoted time to collecting all exotic plant species he could find, as well as any weedy native species that he observed: "General work during the month included the collecting of samples of the introduced weeds appearing on the island . . . The collection of introduced and native weeds is now complete unless further spring plants appear." Sorensen (1944). This collection of exotic plants by Sorensen was undertaken at the request of A. J. Healy, Botany Division, DSIR (W. R. Sykes, pers. comm.).

The first modern, comprehensive evaluation of the flora and vegetation of Raoul Island was undertaken in 1966-67 when Bill Sykes from Botany Division, DSIR, spent three months on the Island as part of the Ornithological Society of New Zealand (OSNZ) expedition. Since that time Bill has been the major advisor to the relevant management authority for Raoul on which plant species should be targetted for eradication. Regular visits to the Island enabled him to assess the progress of eradication programmes and to update the priority lists for eradication efforts.

Following Bill's retirement in 1992, the Department still required advice on the effectiveness and direction of control operations and, as the incumbent weed scientist for Science and Research Division, I was asked to undertake the work. In 1993, I spent ten weeks on Raoul, from May to August, becoming familiar with the flora and vegetation, and investigating the ecology and control of all targetted weed species as well as checking for any recent introductions to the Island. A further visit of eight days was made in October 1994 and this enabled valuable observations during a different growing season.

In this report I give a brief introduction to Raoul Island, then I outline the history of weed eradication operations on Raoul Island and suggest a revised framework for managing the exotic component of the flora. Within this framework I present information on each of the currently or previously targetted species: its history on the Island, ecology, control methods and effectiveness to date, and control operations required in future. The rest of the introduced plant species are listed in two appendices. Thus, the entire exotic flora is considered in this report. Finally, I discuss general points which have a bearing on understanding the ecology of weed species on Raoul Island and the progress of the plant eradication operations on the Island thus far.

2. Raoul Island

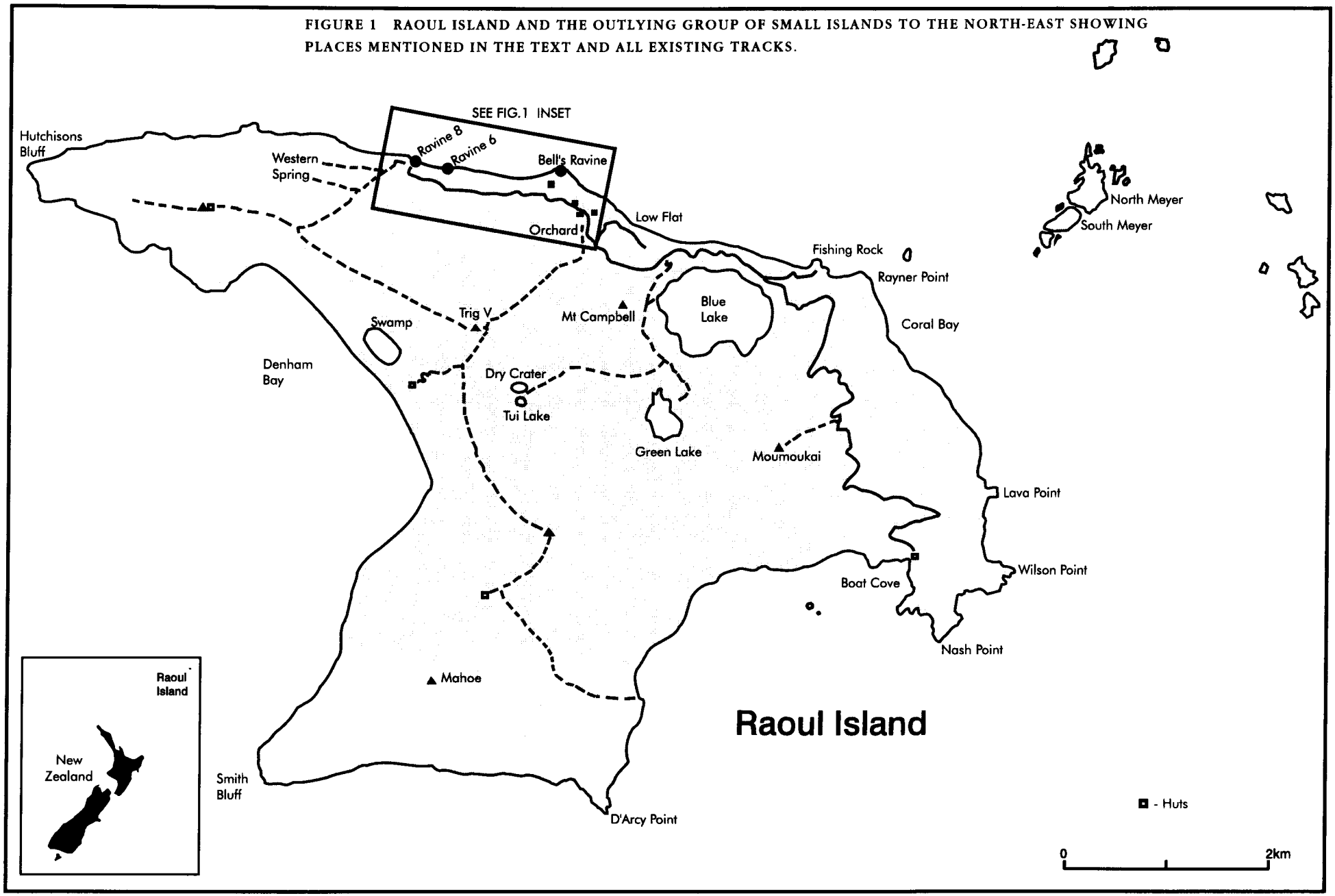
Raoul Island is the northernmost and largest island of the Kermadec Group which lies within the central Polynesian biogeographic region (Udvardy 1975). Raoul is located at 29° 15' S and 177° 55' W. The Island is an active volcano 2943 ha in extent and rising to a maximum height of 512 m above sea level. It is roughly triangular in shape, with a central crater and ridges >300 m high running south (Mahoe Ridge) and west (Hutchisons Ridge) of the crater rim (Figure 1). The crater contains Blue Lake - a large, cool lake with a boggy margin; Green Lake - a smaller, heavily mineralised, warmer lake with thermally active ground at the western end; and Tui Lake - a tiny, mustard-coloured body of water surrounded by tree ferns and pohutukawa forest. The crater rim is steep on its internal faces and there are few points of access, but the floor of the crater is gently undulating. Denham Bay, on the south-west side of the Island, is a 3 km long arching sandy beach with the pohutukawa forest on the flat backed by high cliffs. In the centre of this flat is a large raupo-fringed freshwater swamp. A group of eight small islets is clustered 3-7 km off the north-eastern coast of Raoul. Of significance in this report are the two closest islets - North and South Meyer (Figure 1) - because some of the principal weeds on Raoul are also dispersed to these islets.

All of the islands are young (Quaternary) volcanoes arising from the Kermadec Ridge. Rock types documented from Raoul Island and its outliers include basalt and basaltic andesite, palagonite tuff, and dacite pumice (Lloyd and Nathan 1981). The soils of Raoul Island are highly fertile as a result of the composition of the volcanic material from which they are derived and the climatic regime in which they have developed. The older soils are yellow-brown loams and the remainder are recent soils derived from volcanic ash, with alluvial and colluvial derivatives (Wright and Metson 1959).

Raoul generally lies south of the subtropical convergence and has a warm temperate climate. The mean annual temperature is 19°C with a 3°C difference for mean annual daily maximum and minimum. In winter, 1993, temperatures ranged from 8–23°C. Humidity is generally high (>80%), and annual rainfall averages 1538 mm and is well distributed throughout the year, although October and November have lower rainfall (New Zealand Meteorological Service 1983). In winter west-south-west winds prevail whereas in summer winds blow from the east-north-east. Tropical cyclones are characteristic during the summer months, and have a strong modifying effect on the forests of Raoul Island (Sykes 1977a).

The dominant vegetation on Raoul is *Metrosideros kermadecensis* (Kermadec pohutukawa) forest. Above 300 m is "wet forest" where the principal understorey species is *Ascarina lucida* var. *lanceolata* (Kermadec hutu), in association with *Rhopalostylis baueri* var. *cheesemanii* (Kermadec nikau), *Homalanthus polyandrus* and *Pseudopanax kermadecensis* (Kermadec five-finger). The wet forest lies within the cloud zone and collects moisture from the mist. Below 300 m is "dry forest" and the understorey is principally *Myrsine kermadecensis* (Kermadec mapou), *Coprosma acutifolia* and *Macropiper excelsum* subsp. *psittacorum* (kawakawa).

FIGURE 1 RAOUL ISLAND AND THE OUTLYING GROUP OF SMALL ISLANDS TO THE NORTH-EAST SHOWING PLACES MENTIONED IN THE TEXT AND ALL EXISTING TRACKS.



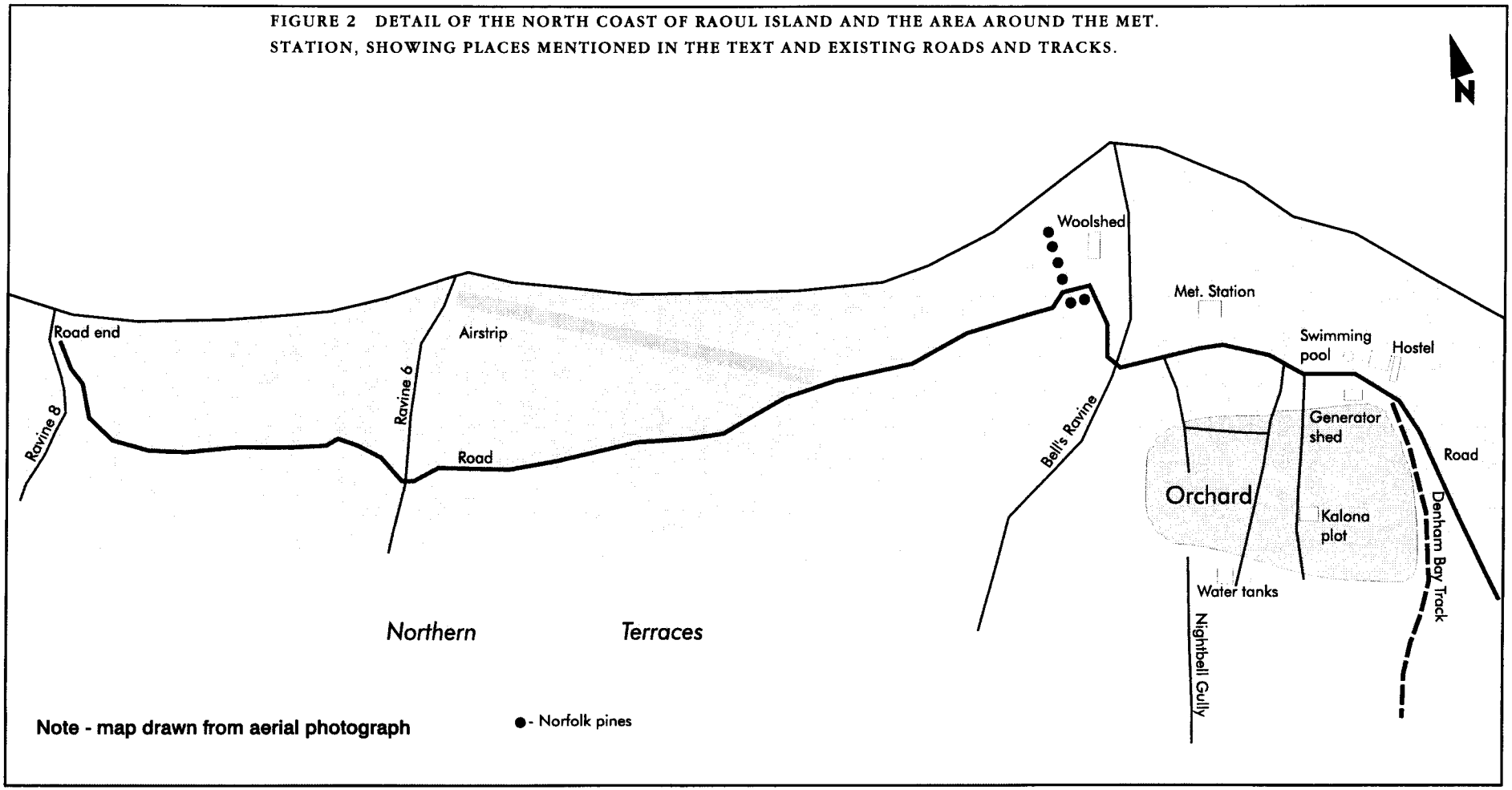
Coastal fringes of the forest typically comprise *Myoporum kermadecense* (Kermadec ngaio), *Cyperus ustulatus* and *Isolepis nodosa.* The forest gradually increases in height with distance from the shore. Grasslands dominated by buffalo grass, *Stenotaphrum secundatum*, are common on the previously inhabited Northern Terraces (Figure 2) and the coastal fringe of Denham Bay. But further from previous occupation sites, the grasslands tend to be dominated by the endemic grass, *Imperata cbeesemanii* and, west of Ravine 8 (Figure 2), the tropical native grass *Cenchrus calyculatus* which has spiny fruits and was dubbed velcro grass by the 1993-94 team. Much of the grassland on the Northern Terraces is composed of introduced species but native grasses are a major component of vegetation on the steep faces of Hutchison's Bluff (Figure 1) and on slips in Denham Bay and other steep sites in coastal places.

There are approximately 300 species of vascular plants recorded from Raoul Island, but almost two-thirds are introduced species, and of those the greatest representation is from grasses. Very few of the introduced species have a major effect on the native vegetation, but some are being eradicated. Others are widespread and dense in places but do not displace forest so there is no need to control them. In time they will be overtopped and eliminated or greatly reduced in extent by the forest.

Raoul Island has considerable natural and historic values. Archaeological evidence indicates that Maori used Raoul as a stopping-over place on their voyages between Aotearoa - New Zealand - and the Pacific (Johnson 1991). Some of that evidence is provided by plant species discussed in this report. Several of the plants brought to Raoul by early European settlers are also of historic significance, and these are discussed as well. There are 23 species of vascular plants endemic to the Kermadecs, and most of these are on Raoul Island. Also, Raoul once was home to the greatest concentration of seabirds ever known from New Zealand but the depredations of cats, Norway rats and kiore have reduced the avifauna to a very low level. Most of the time the forest is silent. Thus, the benefits to be gained from restoration of Raoul by removal of the major plant and animal threats are enormous.

Already goats have been eradicated and this has resulted in greatly increased abundance of most of the endemic plant species. Eradication of the major weed species, as outlined in this report, will enable effective functioning of the forest ecosystem. Finally, eradication of cats and rats will allow seabirds and others, such as the red-crowned parakeet, to return to Raoul from the nearby Meyer Islets. What a wonderful place it will be!

FIGURE 2 DETAIL OF THE NORTH COAST OF RAOUL ISLAND AND THE AREA AROUND THE MET. STATION, SHOWING PLACES MENTIONED IN THE TEXT AND EXISTING ROADS AND TRACKS.



3. History of weed eradication operations

Weed control operations on Raoul Island commenced in 1972 (Devine 1977). The decision to ultimately eradicate certain introduced plants was taken as a result of recommendations of both the 1966-67 OSNZ party and a small group of officials from the Department of Lands and Survey and New Zealand Forest Service - a party from both departments had visited the Island in 1970 to investigate the impact of exotic plants and animals (McMillan 1971). At the outset the introduced vascular plants on Raoul Island were grouped into seven categories:

A Species which so threaten (whether actually or potentially) the preservation of the natural state that their extermination is a desirable and feasible goal.

B Species which so threaten the preservation of the natural state that their extermination is desirable, but is not feasible at the present time.

C Species which need monitoring so that if they appear likely to become aggressive they can be quickly eliminated.

D Species which are known to be vigorous and sometimes aggressive elsewhere but not requiring immediate control.

E Species which may be a potential threat in one habitat and not in another and requiring selective control.

F Species of historical and allied significance which may be protected.

G Specimens of plants in the reserve producing fruit for human consumption which may be protected.

There were six species listed in category A:
Caesalpinia decapetala - Mysore thorn
Psidium cattleianum - purple guava
Psidium guajava - yellow guava
Olea europaea subsp. *cuspidata* - African olive
Furcraea foetida - Mauritius hemp
Hibiscus tiliaceus - shore hibiscus.

It is not known which species were listed in the other categories for Devine's paper (1977) deals only with the category A species.

The plant control programme for Raoul was revised in 1982 (Anon. 1982b) and the number of categories was reduced from seven to five and the definitions were revised. The first two categories remained the same but the next three (C-E) became category C and the last two categories were merged into category D. Category E was a new category. Introduced plants were classified according to their degree of threat to the natural environment (including potential) and those in category A were listed in order of priority for extermination. Eradication was the aim of categories A and E, control for category C, interim protection for category D and no action for category B. The category definitions in 1982 were:

A Weeds" where threat is reversible and covered by current programme for extermination.

B Weeds" where plant invasion is irreversible; no control provided for in current programme.

C Adventives which are a potential threat and are included in the current programme for surveillance and/or limited control.

D Persistent relics of cultivation either of historical significance, a landscape feature or providing edible fruit which may be protected.

E New or recent arrivals which can be exterminated by a short-term operation initiated under the programme before they become naturalised.

The number of species in category A was increased to ten, two species were identified in category B, seven species in category C, an unspecified number of species in category D and three species in category E.

Species in category A were:
Caesalpinia decapetala - Mysore thorn
Senna septemtrionalis - Brazilian buttercup
Psidium cattleianum - purple guava
Psidium guajava - yellow guava
Olea europaea subsp. *cuspidata* - African olive
Passiflora edulis - black passionfruit
Furcraea foetida - Mauritius hemp
Anredera cordifolia - Madeira vine
Foeniculum vulgare - fennel
Hibiscus tiliaceus - shore hibiscus.

Species in category B were:
Alocasia brisbanensis - aroid lily
Stenotaphrum secundatum - buffalo grass.

Species in category C were:
Aleurites moluccana - candlenut (no control)
Populus nigra - Lombardy poplar
Araucaria beterophylla - Norfolk pine (control of seedlings only)
Ricinus communis - castor oil plant
Gomphocarpus fruticosus - swan plant
Phormium tenax - New Zealand flax (no control)
Brachiaria mutica - Para grass.

Species included in category D were:
Cordyline fruticosa - ti
Colocasia esculenta - taro
Prunus persica - peach
and others.

Species in category E were:
Vicia sativa - vetch
Trifolium campestre - hop trefoil
Senecio jacobaea - ragwort.

From 1983-85 the only changes made to the lists were the addition of recently reported species to category E. For example, pampas grass was added in 1984.

In the draft Kermadec Islands management plan of 1986, the same five categories were employed as in 1982 (Sherley 1986). The species listed in Categories A and B were the same. Only Lombardy poplar and seedlings of Norfolk pine were listed in category C. In category D species were not listed but ti, candlenut and adults of Norfolk pine were given as examples. Category E contained the three species listed in 1982 as well as pampas grass.

In 1992, the weed eradication programme was again revised (Anon. 1992) and the number of categories was further reduced, from five to four. The first four categories were essentially the same but the fifth had been dropped. Thus, the categories as they stood in 1992 were:

A Species which so threaten (whether actually or potentially) the preservation of the natural state that their extermination is a desirable and feasible goal.

B Species which so threaten the preservation of the natural state that their extermination is desirable, but is not feasible at the present time.

C Adventives resulting from accidental or deliberate introduction which are a potential threat and are included in the current programme for surveillance.

D Persistent relics of cultivation either of historic significance, a landscape feature or providing edible fruit which may be protected.

The number of species listed in category A was increased to 13 and *Hibiscus tiliaceus* was reclassified from category A to C (Anon. 1992). Two species were listed in category B, nine named species and all other farm weeds in category C, and two named species and all other historical plants introduced for cultivations in category D.

The species listed in category A were:
Caesalpinia decapetala - Mysore thorn
Psidium cattleianum - purple guava
Psidium guajava - yellow guava
Olea europaea subsp. *cuspidata* - African olive
Furcraea foetida - Mauritius hemp
Senna septemtrionalis - Brazilian buttercup
Passiflora edulis - black passionfruit
Anredera cordifolia - Madeira vine
Cortaderia selloana - pampas grass
Araucaria beterophylla - Norfolk pine (seedlings only)
Cirsium vulgare - Scotch thistle
Foeniculum vulgare - fennel
Senecio jacobaea - ragwort.

In category B were:
Alocasia brisbanensis - aroid lily
Stenotaphrum secundatum - buffalo grass.

In category C were:
Ricinus communis - castor oil plant
Tropaeolum majus - garden nasturtium
Trifolium campestre - hop trefoil
Populus nigra - Lombardy poplar
Brugmansia suaveolens - night bells

Brachiaria mutica - Para grass
Hibiscus tiliaceus - shore hibiscus, fou
Gomphocarpus fruticosus - swan plant
Vicia sativa - vetch.

In category D were:
Cordyline fruticosa – ti
Prunus persica - peach.

During the earlier part of the period that the Department of Lands and Survey undertook weed eradication (1972-1981) a small team of people (usually three) worked on the Island for periods of up to six months (Griffiths 1980; Hancox 1982). From the 1981-82 season through to 1987-88 at least one person from that department or the Department of Conservation (1987-88) was stationed on the Island for a year, in association with the staff of the Meteorological Station. Usually more weed control people were sent up from Lands and Survey for a few months to assist the permanent staff member (Sherley 1986). It was during these early days of the eradication programme that the big knockdown spraying regimes for category A species were undertaken. The work was difficult because water sometimes had to be carried considerable distances and there were large areas, particularly of Mysore thorn, to be sprayed. The hot, humid climate made working conditions unpleasant.

In 1989 the Meteorological Service withdrew from the Island as most of their weather data could be collected by an automatic weather station. At this point the Department of Conservation took over management of the facilities on the Island, and the area which had been excluded from the Nature Reserve, as the Meteorological Station and farm, was added to the Nature Reserve. Teams of four people (usually) were stationed on the Island for one-year terms from 1989-90 to the present day. Their primary focus was weed eradication, although the skills of the personnel selected also had to focus on the need to maintain accommodation, communications and facilities on the Island, as well as provide additional weather data on contract to the Met Service.

A chronological list of those staff who have been primarily responsible for weed eradication on Raoul Island is given in Appendix 1.

4. Revised classification for weeds

The entire exotic flora is considered in this report to provide a baseline of what species are present in 1993-94, their general abundance (differences from those noted by Sykes (1977a) are given) and the level of threat posed to the indigenous vegetation. Also, the flora is divided between those which were introduced deliberately for food or decoration and may have historical significance and those which were of accidental or deliberate genesis and are not seen to have any historical significance. Species designated for eradication (category A) may have historical significance but their threat to conservation of the natural state of the Island far outweighs their value as a historical resource.

All of the species previously listed in control programmes are discussed in detail (as outlined in the introduction) and a few species requiring more attention are added to these detailed descriptions. The remainder of the flora is appended in two categories, as indicated above (Appendix 2, 3).

It is apparent that some of the species listed in each category in 1992 do not fit the definitions given for them and that some species should be placed in another category. In addition, the 1992 category B is redundant, for two reasons. Firstly, the two species listed do not pose the threat that was first envisaged, partly because of changes resulting from the eradication of goats. Secondly, we are most unlikely to be in the situation where eradication of these species is feasible. Thus, a revised classification of three categories is suggested:

A Species which so threaten (whether actually or potentially) the preservation of the natural state that their eradication is essential, and recently introduced species which pose a lesser threat whose eradication is achievable.

B Adventives resulting from accidental or deliberate introduction which have no historic significance and which pose a minimal or no threat to the forest ecosystem of Raoul Island.

C Persistent relics of cultivation of historic significance or providing edible fruit which may be protected.

Category A contains all species which must be eradicated, however, this category is subdivided into two sections:

Category A(i) Species which are known to have the potential to significantly alter the structure and composition of the native vegetation of Raoul Island in the long term.

Category A(ii) Species which are unlikely to have long term significant impact on the structure and composition of the native vegetation of Raoul Island but which are of sufficiently low abundance to be eradicated.

Categories B and C comprise all other species, some of which may have to have some degree of control exercised over them. It is important to distinguish

between those species which may have historical significance (category C) and those which do not (category B), given that the Department is charged with protecting resources of historic as well as natural significance. It is possible also, that some of the old cultivars present on the Island (e.g., of grapes, peaches or citrus) could have horticultural value and should be retained on the Island until more is known about them (this is the subject of a separate, rather long term, investigation that I am carrying out). Those species which should be controlled in some locations or should be observed for information on rate of spread or ability to set seed are discussed in detail for both categories. In some cases species listed in category B would have been listed in category A but the opportunity to eradicate them has been missed.

Species discussed in detail within all three categories are:

Category A(i)

Caesalpinia decapetala - Mysore thorn

Senna septemtrionalis - Brazilian buttercup

Passiflora edulis - black passionfruit

Anredera cordifolia - Madeira vine

Psidium cattleianum - purple guava

Psidium guajava - yellow guava

Olea europaea subsp. *cuspidata* - African olive

Cortaderia selloana - pampas grass

Araucaria heterophylla - Norfolk pine
(plants of nonhistoric significance only)

Furcraea foetida - Mauritius hemp

Ricinus communis - castor oil plant

Phyllostachys aurea - walking stick bamboo

Brachiaria mutica - Para grass.

Category A(ii)

Foeniculum vulgare - fennel

Gomphocarpus fruticosus - swan plant

Populus nigra - Lombardy poplar

Senecio jacobaea - ragwort.

Category B:

Alocasia brisbanensis - aroid lily

Stenotaphrum secundatum - buffalo grass

Cirsium vulgare - Scotch thistle

Bryophyllum pinnatum - air plant

Tropaeolum majus - garden nasturtium

Trifolium campestre - hop trefoil

Vicia sativa - vetch.

Category C:

Cordyline fruticosa – ti

Aleurites moluccana - candlenut

Hibiscus tiliaceus - shore hibiscus, fou

Brugmansia suaveolens - night bells

Araucaria heterophylla - Norfolk pine (adults of historic significance only)

Prunus persica - peach

Vitis vinifera - grape

Phoenix dactylifera - date.

The remainder of the exotic species are assigned to either category B or C and are listed at the end of this report (as Appendices 2 and 3, respectively) with brief notes on current distribution and date of first record, if known.

4.1 MODUS OPERANDI

Eradication takes priority over control. Within category A species are listed in order of the perceived threat posed to native vegetation. All will have an impact, but some will spread more quickly than others whereas some will be more difficult to control than others, and the priority order suggested takes into account both of these factors. Within category B species are listed in order of perceived threat and the desirability of control at some locations. The listing in category C is in order of historical value for all species which have ever been listed specifically in an earlier control programme or which may be regarded as weedy to some extent. Thus, when detailing specific work programmes the order of species listings should be taken into account.

5. Category A weeds

SPECIES WHICH SO THREATEN (WHETHER ACTUALLY OR POTENTIALLY) THE PRESERVATION OF THE NATURAL STATE THAT THEIR ERADICATION IS ESSENTIAL, AND RECENTLY INTRODUCED SPECIES WHICH POSE A LESSER THREAT WHOSE ERADICATION IS ACHIEVABLE.

Category A(i) *Species which are known to have the potential to significantly alter the structure and composition of the native vegetation of Raoul Island in the long term.*

5.1 *Caesalpinia decapetala* – MYSORE THORN

5.1.1 History

Sykes (1977a) states that the first reference to this species on Raoul comes from Carver's (1889-93) plan of Bell's garden in Denham Bay in 1891, where he included an "acacia" forming part of the boundary. Neither Cheeseman (1888) nor Oliver (1910) recorded Mysore thorn as a naturalised plant and presumably, at that stage, it was still fulfilling its primary function as goat-proof fencing for the plantations (Sykes 1977a). The Bell family had lived on the north side of the Island probably since early 1880 (Johnson 1991) but continued to farm at Denham Bay for as long as they could. Thus, some form of fencing to exclude goats and sheep from plantations would have been necessary.

In 1937 Davison (1938) noted that "acacia" had been introduced to Raoul by settlers. In maps appended to the report of the Aeradio Committee (of which Davison was part) the acacia is marked to the north-west of the swamp in Denham Bay, in the area initially occupied by the American settler Halstead (Johnson 1992). Aerial photographs of Raoul Island taken on 29 January 1943 show clearly a large, almost continuous infestation of Mysore thorn extending back towards the cliffs at the north-western edge of Denham Bay swamp. At this date, the extent of the infestation is calculated as being 4 ha. In 1944, Sorensen (1944) observed that dense clumps of a thorny acacia which extended over many square chains of the Denham Bay flat near the swamp and back at the foot of the cliffs, were up to 20 ft high in places and had "choked out quite an area of native plants and two large orange trees". He noted that it was flowering profusely (in August) and was extending its range, and he regarded it as harmful to native vegetation. Sorensen also reports from Davison (who was on the Island again in 1944) that the Mysore thorn had vastly increased since 1938.

Davison (1938) knew about the Mysore thorn, but did not regard it as a serious threat to the native vegetation of the island, as he states in his report: "Apart from the arum [*Alocasia brisbanensis*] and cherry pie [*Ageratum*

houstonianum] and a creeping plant like a cucumber but with a bunch of seed head covered with hairy spines [*Sicyos australis* - a native species], the Island is remarkably free from weeds of a harmful nature, and special efforts should be made to keep it so, and care should be taken that undesirable plants are not introduced with the packing straws, etc., of imported stores." Obviously, Davison and Sorensen discussed the Mysore thorn in Denham Bay when they were both on the Island in 1944 (Sorensen 1944), but it was not until 1967 after the OSNZ party had visited Raoul that concern was expressed to the Department of Lands and Survey of the threat the Mysore thorn posed to indigenous vegetation of the Island. Bill Sykes, botanist on the expedition, recommended eradication (Merton 1969).

Aerial photographs of Raoul Island taken on 26 November 1964 unfortunately do not cover Denham Bay. Sykes (1977a) records that in 1966 and 1967 Mysore thorn was growing over considerable areas of Denham Bay and that the stems climbed to nearly 20 m. In his view, the Mysore thorn seemed to threaten the indigenous vegetation of Raoul more than any other introduced plant. In 1972, Mysore thorn was estimated to cover 16 ha in Denham Bay, and by 1974, the area covered was more accurately estimated to be 22 ha (Devine 1977). Control of Mysore thorn in Denham Bay commenced in 1974 with aerial application of Tordon 2G but the area covered was less than that originally intended because of hopper failure during the operation. When Atkinson visited Raoul in 1975 he also estimated the area of serious infestation to be 22 ha, based on measurements from aerial photographs taken on 29 July 1975. A smaller infestation of 1.1 ha was noted south of the Denham Bay swamp and other smaller clumps were seen (Atkinson 1975). Thus, one year after the control operation commenced there was no obvious reduction in the area occupied by Mysore thorn. The effect of the first application of Tordon was to kill about 90% of an infestation but some stems survived and seedlings germinated through the area, although not abundantly (Atkinson 1975). In 1975 Tordon was again applied aerially by helicopter to the worst areas of Mysore thorn infestation in Denham Bay (Atkinson 1975).

The extent of mature vines was reduced rapidly by the use of chemicals and burning, and during the 1980s Sykes (1980, 1984, 1990), on his regular visits to Raoul, saw only seedlings on the flat in Denham Bay. In 1980, he strongly recommended that burning of the fern-covered clearings be continued, to hasten the decline of the Mysore thorn seed bank. Hancox (1982) worked on Raoul in 1981 and stated that much of the original infestation was under control and in future more time would be spent "pushing through the undergrowth to look for the individual plants". When Sykes visited in 1984 he formed the same opinion, stating that blanket spraying and burning of areas was no longer required and that control would consist of hand pulling of seedlings and spot control of larger vines (Sykes 1984). Bracefield (1987) removed 2146 vines from Denham Bay and blanket sprayed one area. Gardner (1988) killed a total of 5468 plants. Aerial photographs taken on 2 March 1992 show no trace of Mysore thorn in Denham Bay. Although Mysore thorn was present at this date, it was limited to single, small plants which are not detectable on aerial photographs. Several seeding vines were killed in 1993 (pers. obs.) and in 1994 two seeding plants, several flowering plants and hundreds of seedlings were removed from Denham Bay (Fastier 1994). There have been no more seeding

adult plants found since then although more seedlings and non-flowering vines up to 6 m long have been removed (Uren 1994).

The Mysore thorn growing on the cliffs behind the bay has been difficult to gain access to, but careful climbing and abseiling to each plant have enabled effective control. The cliffs have been a focus of Mysore thorn eradication since 1974, including aerial operations, and Sykes (1980, 1984, 1990) has consistently reminded weed workers of the need to destroy these plants. Today the cliffs remain the most difficult point of control and three sites containing flowering vines were observed by Uren (1995b). These are targetted for control.

An infestation of Mysore thorn has been known of towards the head of Ravine 8 (see Figure 2) since before 1972 (Devine 1977). In 1972 this infestation was estimated to cover c. 1000 m^2. From 1972-73 the Mysore thorn at this site was used in trials to evaluate the effectiveness of Tordon 2 G granules. In 1975, after widespread use of this herbicide on the Ravine 8 infestation, only two vines and 39 small seedlings remained alive; the seedlings were pulled out (Atkinson 1975). In 1976, seven vines were recorded at this site (Trotter 1976). Ombler (1977) reports that in 1977 there was an area of dense Mysore thorn regeneration at the lower end of the plot and 50 seedlings were scattered over most of the original plot area. The seedlings were pulled by hand and the dense patch sprayed with Tordon 520. In 1978, 21 seedlings were removed (Dale (1979) and in 1979 13 seedlings were pulled out (Adlam 1979). No plants were found in 1982 whereas in the previous year two plants were noted growing from old rootstock (Selby 1982a). Sykes (1984) found one large plant in this site which had not been checked for over a year. In 1990 only two plants were present and these were both killed (Clapham 1991a). The site has been checked regularly since then and no further plants have been found.

5.1.2 Ecology

Mysore thorn is a scrambling spinous vine with narrow pinnate leaves, in the legume family (Fabaceae). This vine will grow at least as tall as the vegetation which supports it and when growing on Kermadec pohutukawa, therefore, it will grow up to 20 m tall (Sykes 1977a). The species is light-demanding and germinates only in high light environments, such as canopy gaps dominated by ferns (*Histiopteris incisa* and *Hypolepis dicksonioides*) or open areas on the cliffs behind Denham Bay. Occasionally plants will germinate in areas dominated by ladder ferns (*Nephrolepis* cf. *cordifolia* and *N. hirsutula*) beneath a light and sparse canopy, and they will be straggly until they reach the canopy. Once in the light they will grow prolifically and quickly spread across the canopy. In 1982, Selby (1982b) reported for the first time that Mysore thorn does flower within its first year. Within seven months plants had germinated, grown up to 2 m in length and were flowering. He noted, also, that this vine will flower when beneath a fern canopy.

Growth of plants is rapid. Rees (1982) monitored the growth rate of nine seedlings from a range of situations in Denham Bay (Table 1). He found that plants seemed to grow slowly up to 800 mm tall and then grew rapidly. The initially slow growth rate was assumed to be a result of competition with ferns, aroid lily and nightshade (*Solanum americanum*). Sykes (1990) warned that Mysore thorn could flower and form fruit in well under two years in good

conditions and noted that nine-month-old plants were flowering. Samson (1993a) observed that seedlings could grow up to 2 m in a few weeks and could be setting seed when only 4-6 months old. Young plants are cryptic. Frequently they germinate among water fern (*H. incisa*) and the shape and colour of the water fern and the Mysore thorn are so similar that many young plants remain undetected. Even when growing up a trunk on the edge of a light gap, young plants can be missed easily. However, as soon as the plants commence flowering the bright yellow flowers are very visible (Figure 3), and the plants are easily detected from any distance. Plants usually flower from June through to November. The length of time from flowering to seed set is not known but seed pods are persistent and can be found year round on adult plants.

Seed pods contain 7-10 small, brownish seeds which have very hard seed coats. The seeds can remain dormant in the soil for a number of years (a characteristic of many legumes) and usually germinate when they are exposed to light. Thus, soil disturbance in areas previously occupied by Mysore thorn is likely to result in exposure of seeds followed by seedling germination. Ombler (1977) reported that hundreds of Mysore thorn seedlings had sprouted in slips

TABLE 1 GROWTH DETAILS OF NINE MYSORE THORN SEEDLINGS AT DENHAM BAY (REES 1982).

	PLANT NUMBER (HEIGHT IN mm)								
DATE	1	2	3	4	5	6	7	8	9
5/12/81	40	-	40	-	50	-	50		30
3/1/82	200	-	90	280	170	-	110	100	80
9/2/82	310	400	200	410	270	170	180	170	160
3/3/82	450	420	340	540	490	305	440	200	320
2/4/82	450	450	340	720	800	460	500	200	360
4/5/82	450	510	350	1000	900	640	500	210	500
1/6/82	530	580	420	1000	1060	830	690	350	590

Details of plants

Plant 1: burnt area among nightshade.
Plant 2: fast plant in burnt area died, another selected just outside burnt area.
Plant 3: burnt area among nightshade, nearly died in January.
Plant 4: bush edge under tree canopy among aroid lily and ferns.
Plant 5: among old vines on top of large rock with very little soil.
Plant 6: old slip near a large rock, among old vines and aroid lily.
Plant 7: among old vines and aroid lily just under tree canopy.
Plant 8: on track under bush canopy.
Plant 9: burnt area among young nightshade and fern.

Figure 3 Mysore thorn flowering in a ferny clearing in Denham Bay, August 1990 (Photo: W.R. Sykes).

Figurc 4 Knapsack spraying of Mysore thorn in Denham Day, 1976 (Photo: J. Trotter).

along the base of the cliffs which were caused by earthquakes in 1976. Mysore thorn seeds are not normally dispersed far from the parent plant. Champness (1975) noticed that the pods open facing upwards and the seeds lie in the open pod until disturbed by wind or rain. Thus, seeds are likely to be dispersed only a few metres away and, in general, seedlings are most likely to appear where adult plants have been. Occasionally, however, longer distance dispersal can occur. The small infestation in Ravine 8 that was discovered in the early 1970s may have resulted from seed dispersed by humans or by wind. Although wind dispersal sounds unlikely, it is possible. Ravine 8 is due north of the largest area of Mysore thorn in Denham Bay and during periods of strong winds, the ravine acts as a wind funnel. Atkinson (1975) suggested that a whole seed pod could have been carried to this site in an exceptional gale.

Essentially, the pattern of spread of Mysore thorn is predictable. Seeds are not dispersed far from parent plants and will germinate in high light environments. Seeds may persist in the soil for many years so areas where plants have grown need to be checked regularly for years to come. The only practicable point in the life cycle to exert control is before seed set. The aim is to halt any further additions of seed to the seed bank, thereby reducing the length of time that surveillance and control needs to be implemented. Mysore thorn can be searched for and found at any time of year but is easiest to spot when it is flowering. Therefore, control work must be carried out consistently over the flowering period (June to November) to catch plants while they are flowering but before they set seed.

5.1.3 Control methods

In the past, several control methods were used: aerial and ground-based application of herbicides, and burning. The earliest trials (1972-74) established that Tordon 2G granules could kill large, cut vines (Devine 1977). At the start of the control operation in Denham Bay, the initial knockdown was achieved by aerial application of Tordon 2G granules from a helicopter in a pattern which would open up the Mysore thorn canopy sufficiently to allow ground operations to be carried out in subsequent years. In 1975 all of the the Mysore thorn visible from the air was treated in six hours of flying time and this resulted in an estimated kill rate of >70% (Champness 1975).

The ground-based operations relied on a water pipeline system which was reticulated through the worst infested areas. Spray operators attached a motorised knapsack unit to the pipeline to spray Mysore thorn with Tordon 520 'Brushkiller' (Figure 4). The densest infestations were controlled in this way until at least 1986. By this time the pipeline was breaking down and knapsack spraying was continued for the worst infestations, without the use of the pipeline. Saltwater was often used instead of freshwater (e.g., Ombler 1977). Isolated plants and small seedlings were hand-pulled (Bracefield 1987). In 1991-92, plants were hand-pulled, if small enough, or cut and treated with Tordon 2G granules (Clark 1992).

Burning was also used in clearings dominated by Mysore thorn, as recommended by Sykes (1980). A trial in 1980 established that Mysore thorn could be killed by burning, and the other advantage was that baring the soil to that degree would enhance germination of Mysore thorn seeds, thereby

exhausting the seed bank more quickly (Sykes 1980). In 1982, five Mysore thorn plots were successfully burnt in Denham Bay. A further plot was not burnt because of lack of water (Selby 1982c). Since 1982 fire has not been used as a control method, possibly because most of the regeneration was of native species and young Mysore thorn could be more easily removed as individuals.

Currently Mysore thorn control is achieved by systematically searching the Denham Bay flats and cliffs and hand pulling all plants. Pulled plants are hung up in nearby vegetation to desiccate. Those plants which are too big to pull out are cut and Tordon 2G granules are scattered at the base of the plant. If any plants have set seed, as much seed as possible is collected, then taken back to the Hostel and destroyed.

5.1.4 *Future work*

The current method of Mysore thorn control should be continued for an unspecified number of years into the future. The unknown factor is the length of time that seeds can remain viable in the soil. Slips can occur at any time on the cliffs at Denham Bay - prompted by earthquakes or heavy rain (both of which are common phenomena) - and any freshly bared soil could contain viable Mysore thorn seeds. Ground can also be bared on the flats, through the uprooting of trees during cyclones, or through flooding. In 1993 several seeding vines were destroyed but they had already dispersed fresh seed. Even if no more Mysore thorn plants set seed on the Island from 1993, it could still be ten years (but most likely more) before viability of seeds in the seed bank is reduced to zero. The Ravine 8 site should be checked annually. Constant surveillance and immediate control are the keys to Mysore thorn eradication.

5.2 *Senna septemtrionalis* – BRAZILIAN BUTTERCUP

Previously *Cassia floribunda*

5.2.1 *History*

Brazilian buttercup was presumably introduced to Raoul Island as an ornamental shrub because that is the normal purpose for introduction of this species to other countries (Sykes 1977a). Because the species was not recorded as a cultivated or naturalised plant by Cheeseman (1888) or Oliver (1910), it is assumed that it was introduced this century. Sorensen (1944) did not record this species among his naturalised plant collections. By 1967 Brazilian buttercup was naturalised in the forest from the Hostel eastwards for c. 2.5 km (Figure 5), in gullies from Low Flat to Ravine 8, in the old Denham Bay plantations, near Boat Cove and at Blue Lake (Sykes 1977b).

Brazilian buttercup was also present on North and South Meyer (Taylor 1974, Sykes 1977a). Sykes (1984) later recorded this species as widespread and common on the middle and upper western faces of South Meyer and present, but less dense and more localised, on the western side of North Meyer. In c. 1985, Chandler (n.d.) commented on the contrasting growth form of the Brazilian buttercup on the Meyers and on Raoul. On the Meyers, the plants were

Continue to next file: srs98a.pdf