# Eradication of rabbits and mice from subantarctic Enderby and Rose Islands

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**Abstract** In 1993 rabbits (*Oryctolagus cuniculus cuniculus*) were eradicated from Enderby (700ha) and Rose (80ha) islands in the New Zealand subantarctic Auckland Island group. This was achieved by a widespread poison campaign followed by an intensive second phase which included hunting with a dog, spotlighting and trapping. During the poison campaign a helicopter was used to apply a cereal pelleted bait incorporating the anticoagulant toxin brodifacoum to both islands. Mice (*Mus musculus*), which were present on Enderby, disappeared during the poison campaign and appear to have been eradicated during this phase. The potential impacts to non-target species were assessed prior to the operation. Although the poisoning had a notable short-term impact on skua (*Stercorarius skua lonnburgi*) numbers there has been no obvious long-term impact on any non-target species. Rabbits and mice were the last of several introduced mammal species to be removed from Enderby and Rose. Without them the unique ecological values of these islands have a chance to recover.

**Keywords** Eradication; rabbits, *Oryctolagus cuniculus cuniculus*; mice, *Mus musculus*; Auckland Islands; Enderby Island.

## INTRODUCTION

The Auckland Islands are an uninhabited subantarctic group lying 460 km south of New Zealand, at approximately 50°40' S, 166°08' E. The group consists of two large and five smaller islands and numerous small islets (Fig. 1). The two largest are Auckland Island (46,000 ha), which rises to a maximum altitude of 664 m, and Adams Island (9900 ha), which rises to 667 m. At the northern end of the group, around Port Ross, there are four smaller, low-lying islands, the largest two of which are Enderby (700 ha) and Rose (80 ha) Islands (Fig. 1). The Auckland Islands are gazetted as a National Nature Reserve (Reserves Act 1977) and are of international ecological importance because of their particularly diverse and unique biological communities, which include many endemic species of plants and animals such as Auckland Island teal (*Anus aucklandica aucklandica*), snipe *(Coenocorypha aucklandica*) and Auckland Island rail (*Rallus pectoralis aucklandica*) (Penniket *et al.* 1987). They are also an important breeding ground for marine mammals and seabirds including New Zealand sea lion (*Phocarctos hookeri*) and wandering albatross (*Diomedea exulans*).

Since their discovery in 1806, the islands have been subjected to significant human impacts. These include the introduction of a variety of alien mammals, at first by sealers or as food for castaways, and later during attempts at farming. Some of these animals have died out naturally, but in recent times Auckland Island has continued to be host to pigs (*Sus scrofa*), goats (*Capra hircus*), cats (*Felis catus*), and mice; Enderby Island to cattle (*Bos taurus*), rabbits, and mice; and Rose Island to rabbits (Fig. 2) (Taylor 1968, 1971).

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Since 1987, New Zealand's Department of Conservation has actively pursued a policy, set out in the Management Plan for these islands, to eradicate all alien animals as soon as is feasible (Penniket *et al.* 1987). Goats were eradicated from Auckland Island between 1989 and 1991 (A. Cox pers. comm.). The majority of cattle were removed from Enderby in 1991, with eradication being completed by the rabbit eradication team in 1993. In 1991, the feasibility of removing rabbits from Enderby and Rose Islands was investigated. Based on the results of that investigation, a programme aimed at the total removal of rabbits

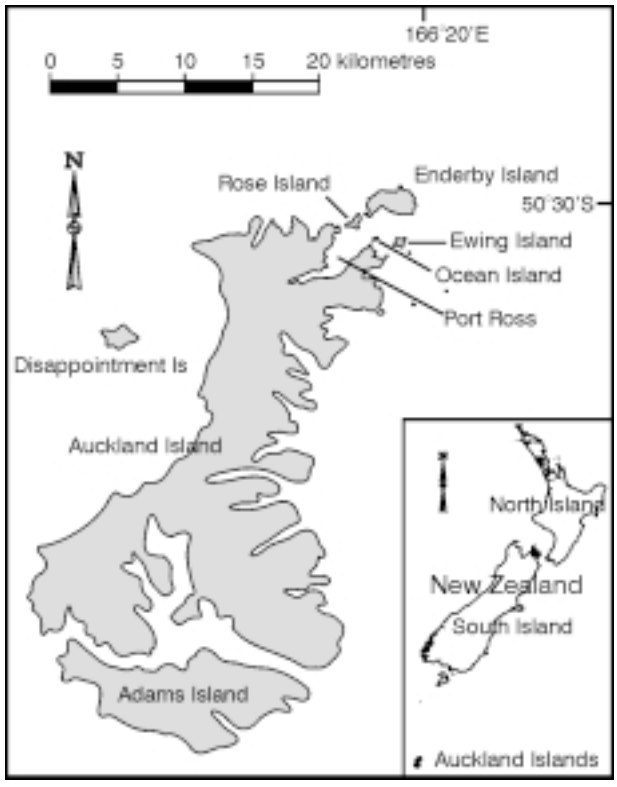


**Fig. 1 The Auckland Islands showing the location of Enderby and Rose Islands, and other places mentioned in the text.**

Pages 319-328 In Veitch, C. R. and Clout, M. N. (eds.). *Turning the tide: the eradication of invasive species*. IUCN SSC Invasive Species Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK.

from both islands was instigated. During the investigation and planning for this operation it became apparent that there could be an opportunity to eradicate mice from Enderby at the same time as rabbits. This was adopted as a secondary aim of the eradication programme.

The proposed programme presented some challenging features, including:

- the difficulty of carrying out an eradication operation in an isolated situation far (460 km) from the New Zealand mainland, under unfavourable climatic conditions;
- the size of Enderby, which at 700 ha, is much larger than any island from which rabbits and mice had previously been eradicated (Round Island at 151 ha and Mana Island at 217 ha respectively) (Merton 1987; Hook and Todd 1992).
- the presence of some indigenous birds, considered to be at risk from some of the methods used in the eradication programme.

This paper reports the progress of the eradication programme from initial bait trials in 1991. It covers the 1993 eradication operation and the following period of monitoring.

## Description of Enderby and Rose Islands

Both islands are comparatively low-lying, with Enderby Island rising to a maximum altitude of about 45 m and Rose slightly higher at 48 m. Except for two sandy beaches on Enderby and a few sections of steeply sloping shoreline, both islands are almost completely surrounded by coastal cliffs. These rise to over 30 m on their northern and western shores, but are generally lower on the southern and eastern coasts. Apart from about 30 ha of sand dunes on Enderby Island, both islands are covered in a thick blanket of peat, which in many areas is waterlogged.

Since their discovery, modification to the original vegetation of these two islands has been quite severe, mainly through the use of fire during failed farming attempts in the late 1800s and the presence of introduced mammals (Fig. 2) (Taylor 1968, 1971).

Along the southern and eastern sides of both islands, and covering about one quarter of their surface areas, is a belt of southern rata (*Metrosideros umbellata*) forest and scrubland. The rest of Rose Island is predominantly covered by large areas of *Poa litorosa* tussock grassland interspersed with areas of short sward vegetation. On Enderby, the centre of the island and about one third of its area is moorland dominated by the shrub *Cassinia vauvilliersii* and cushion plant *Oreobolus pectinatus* interspersed with isolated patches of rata forest and *Myrsine divaricata* scrub. Around the coast is a band of short sward vegetation, which is extensive on the northern and western side, and up to several hundred metres wide in some places.

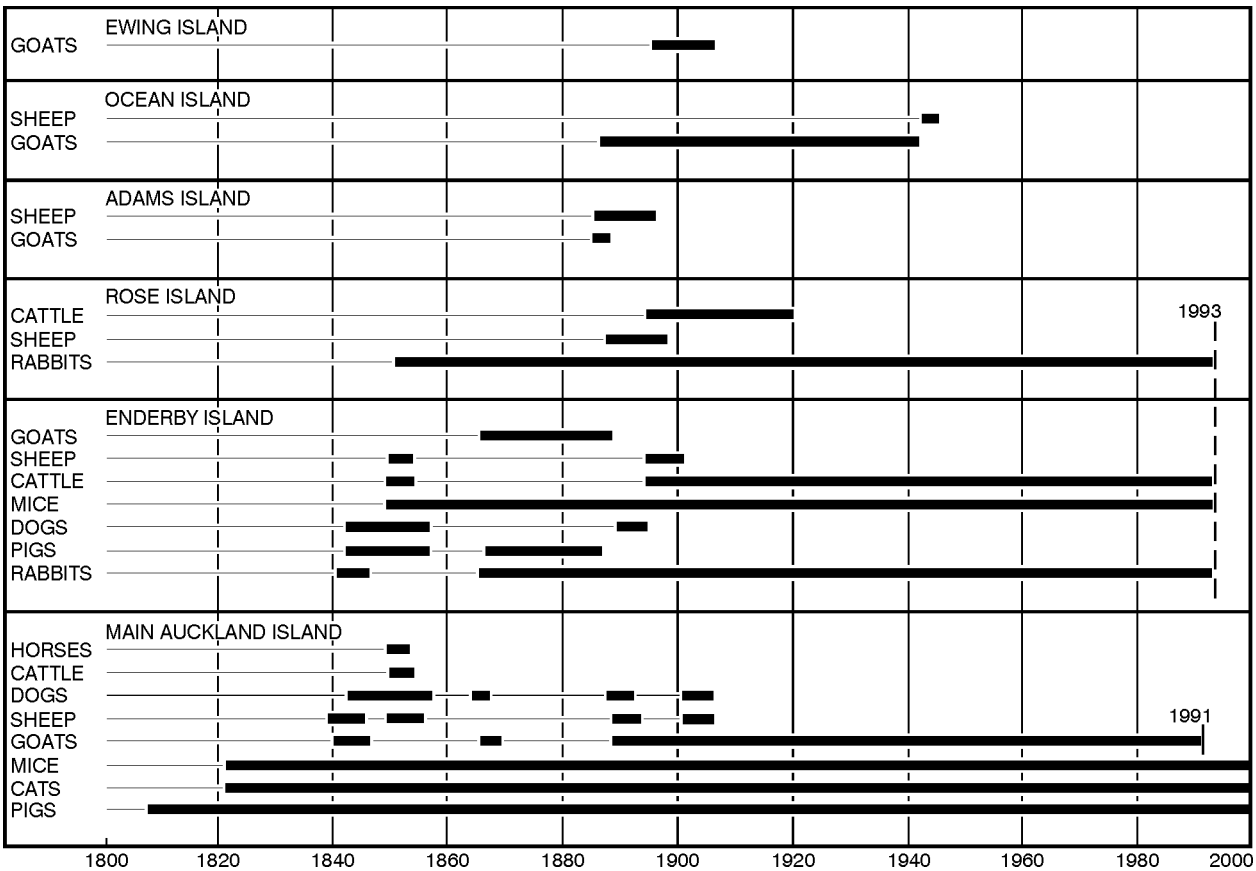


**Fig. 2 Historical summary of introduced mammals on the Auckland Islands (updated from Taylor 1968). The thick bars indicate when each species was present.**

Prior to the eradication, cattle and rabbit browsing had confined the large-leafed herbaceous plants *Stilbocarpa polaris* and *Anisotome latifolia* to cliff areas and *Pleurophyllum criniferum* had been eliminated from both islands. On Enderby Island, tussock grasslands had been almost eliminated and replaced with a closely-cropped sward made up of a mixture of both introduced and native plants.

## History and effects of rabbits on Enderby and Rose Islands

Rabbits were liberated on Rose Island in about 1850, during a period of attempted settlement in the Port Ross area. The liberation was probably of mixed stock, or there may have been other unrecorded liberations, as the population there included agouti and silver black rabbits, both with and without white markings (Taylor 1971).

The rabbits on Enderby were descended from 12 animals liberated in 1865 to establish a population as food for castaway mariners (Taylor 1971). They came from the Acclimatisation Society of Victoria in Australia and belonged to the French breed known as "Argenté de Champagne" (or French Blue). The rabbits on Enderby had bred true to this type (Taylor 1971). Argenté de Champagne is now a fairly rare breed and it was thought that the Enderby population might have been the last true wild population left in the world (B. W. Glentworth pers. comm.). Before the eradication, 49 rabbits were recovered from Enderby Island by the Rare Breeds Conservation Society of New Zealand and the Department of Conservation, and brought back to New Zealand to form the nucleus of a managed captive population.

During a visit to Enderby Island in 1991, Glentworth mapped the density and distribution of rabbits by walking several circuits of the island during periods of high rabbit activity at dawn and dusk and at night with a spotlight (Fig. 3). He then compared the number of rabbits seen as well as the amount of scratchings and droppings observed to areas of known rabbit density on mainland New Zealand. From this method he estimated the total population at 5000-6000 animals. On Rose Island, density, distribution, and numbers of rabbits were much harder to estimate because of the thick ground cover of *Poa litorosa*, but the total population was probably 300-400 individuals. Estimated rabbit density for both islands ranged from >35 animals per hectare in the more favoured habitat around Sandy Bay on Enderby Island, to <2 animals per hectare in less favourable habitat. In general, rabbits were more numerous on Enderby than Rose Island. Rabbit sign was found over all areas of both islands, including the rata forest (B. W. Glentworth pers. comm.).

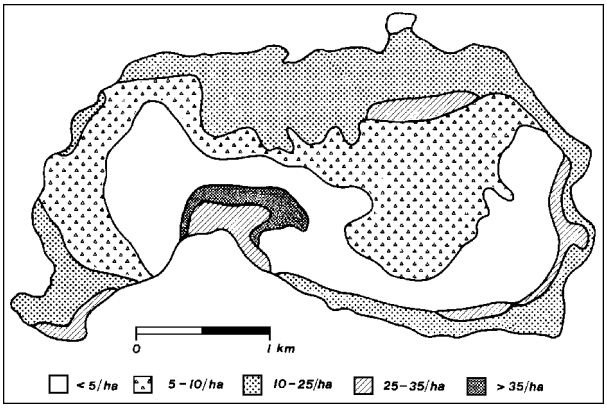


**Fig. 3 Distribution and estimated density of rabbits on Enderby Island, Feb 1991 (Glentworth pers. comm.)**

In addition to their impacts on vegetation, rabbits also reduced the survival of New Zealand sea lion pups on Enderby Island. New Zealand sea lions are found only within New Zealand waters and are a threatened species. Sandy Bay on Enderby Island is an important breeding site for them. The numerous rabbit burrows around Sandy Bay proved a hazard to sea lion pups, which became trapped in them and died. Mortality from this cause was estimated as up to 10% of pups on Enderby Island in some years (Penniket *et al.* 1987).

## History and effects of mice on Enderby Island

Mice were accidentally introduced to Auckland Island during the main period of sealing activity in the early 1820s (Taylor 1968). They probably arrived on Enderby about 1850, when there was an increase of human activity on the island associated with a period of attempted settlement in the Port Ross area (Taylor 1971). They have thrived since then and, prior to the eradication programme, were widespread across the whole of the island and were often seen in large numbers around the hut and old boatshed at Sandy Bay.

Little is known about the direct effect mice have had on Enderby Island ecosystems, but it is likely that predation had a profound influence on the invertebrate fauna. It is also possible that they have had some influence on vegetation through eating seeds and young shoots.

# METHODS

## Eradication strategy

The rabbit eradication programme was designed to follow a similar strategy to that used for the successful eradication of rabbits from Round Island, Mauritius, in 1986 (Merton 1987) and involved two distinct phases. The aim of the first phase was to lower the total rabbit population quickly and substantially. This would be achieved with two aerial applications of poison bait spaced approximately 14 days apart and applied to the total surface area of both islands.

Experience gained from other rabbit poisoning operations indicated that it is unrealistic to expect all rabbits exposed to poison bait to succumb. After the poison operation on

Round Island, 14 rabbits were shot during the following period of hunting. At least one of these showed no signs of poisoning and had apparently not fed on bait (Merton 1987). During the eradication of rabbits from Whale Island in the Bay of Plenty, New Zealand, some rabbits avoided eating some types of poison bait, despite being exposed to several applications (Jansen 1993). Thus a second phase was planned to track down and destroy any rabbits left after the initial poison operation.

The second phase was to start one week after the second application of poison, by which time most rabbits affected by the poison were expected to have died. A variety of methods were chosen including hunting with a dog, shooting, spotlighting, and trapping. This would require a team of dedicated and experienced hunters with a dog to be on the islands for two months after the poison operation. Visits to the islands by the same or a similar team were also planned for the following years until no live rabbits remained.

Although mice had been eradicated from five islands (up to 217 ha) off the New Zealand coast, using ground-administered second-generation anti-coagulant poisons (Veitch 1994; Hook and Todd 1992; Brown 1993), they had never been eradicated using only aerial application of a poison bait. However, recent success at eradicating Pacific rats (*Rattus exulans*) from islands up to 225ha (Veitch 1994) using a single aerial application of poison bait similar to the type we intended using for rabbits, led the project planning team to believe there was a strong possibility that mice could be eradicated at the same time as rabbits. Although the major effort of this campaign was always focused towards rabbits, some steps, as noted later in this paper, were taken with the application of poison to increase the chances of also eradicating mice.

To establish whether eradication had been successful required the island to be monitored for two years after the last sign of live rabbits and at least four years after the last mouse sign was seen. If rabbit sign was still found three years after the initiation of the eradication programme, progress would be reviewed with serious consideration given to continuing the programme.

## Logistics for the Eradication Programme

A team of four people and one specially trained rabbit tracking dog were stationed on Enderby Island from 9 February to 8 May 1993, and two of the original four people and the same dog were stationed there from 20 January to 19 February 1994. Visits to Rose Island were made regularly through these periods using a 3.5 m dinghy with outboard motor. A helicopter flew from New Zealand to the Auckland Islands twice during the first period to spread poison bait.

## Choice of bait

Three important aspects were considered when deciding the most suitable bait: (1) palatability to target and non-target organisms, (2) ease of handling and storage, (3) effectiveness in wet conditions. Two bait types commonly used for rabbit poison operations in New Zealand – diced carrot and cooked oats – were not considered because of the logistical problems of keeping bait fresh, the need to prepare bait on site, and potential non-target problems. Instead, trials concentrated on several types of manufactured cereal-based pellets. These were considered the most appropriate bait type for this operation because: (1) they may be pre-loaded with toxin and kept in storage for extended periods of time, (2) no preparation is required on site, and (3) they are light and easy to handle. They are also known to be highly palatable to rabbits and rodents.

An important consideration was how well bait would stand up to climatic conditions and remain effective once laid. The Auckland Islands have a relatively wet climate. An average of over 1400 mm of rain falling over more than 300 rain days per year was recorded in the Port Ross area during 1941-1945, the only period continual records have been kept (De Lisle 1965). Cereal pellets are known to break down fairly quickly in wet conditions. The possibility of toxin being leached out of bait was also considered. For each poison drop to be most effective, bait was required to remain palatable and toxic for at least three nights after the drop.

During two trips to Enderby Island in 1991 and 1992, acceptance and preference trials of several bait types were conducted *in situ* (B. W. Glentworth pers. comm.; W. P. Costello pers. comm.). The bait preference trials indicated that Enderby Island rabbits ate all bait types tested in preference to natural foods and had no significant preference for any one bait type. However, it was noted that "Wanganui No. 7" (manufactured by Animal Control Products, Wanganui, New Zealand), while by no means waterproof, had superior weathering characteristics to the other bait types tested. For this reason Wanganui No. 7 was chosen for this operation.

A bait acceptance trial with Wanganui No 7 was also conducted using "Rhodamine B" (Tetra-ethyl rhodamine) as a biotracer. Baits were presented over a 5 ha area of high rabbit density in a manner resembling as closely as possible the planned bait drop. After three nights a sample of 46 rabbits was shot. All tested positive, indicating total acceptance of the bait by rabbits (W. P. Costello pers. comm.).

During the bait trials mice showed considerable interest in all bait types tested. In some trials up to 15% of the bait was consumed or partially eaten by mice (B. W. Glentworth pers. comm.).

## Choice of toxin

Brodifacoum was chosen as the most appropriate poison for this campaign. A second-generation anticoagulant, it was the poison used to eradicate rabbits from Round Island (Merton 1987) and has also been used for the majority of successful rodent eradications from islands around New Zealand. Advantages over most other available poisons included:

- It is extremely toxic to rabbits and mice. The LD50s for these species are 0.29mg/kg and 0.4mg/kg respectively (Hone and Mulligan 1982). This allows very low loadings of toxin, which reduces the risk of primary and secondary poisoning of non-target animals.

- The onset of symptoms does not occur for several days after poison has been consumed. Therefore, animals have plenty of time to consume a lethal dose before feeling any ill effects and poison shyness is unlikely to develop. This means that pre-baiting is unnecessary.

- A lethal dose of poison can be ingested in a single feed or accumulated during several feeds over an extended period of days. This makes it more likely that every animal will obtain a lethal dose of poison, thereby reducing the chances of sub-lethal poisoning and subsequent development of poison shyness.

- Animals normally take several days to die after ingesting a lethal dose of poison, becoming progressively weaker in the hours before death. Because of this, many animals die underground or in cover, therefore reducing the risk of secondary poisoning of scavenging birds such as skuas.

- Brodifacoum is not soluble in water and is therefore slow to leach from baits in damp conditions. When released it binds onto organic matter in the soil and is rendered inert. Soil microorganisms then slowly degrade it over a period of 3-6 months (Shirer 1992).

- Brodifacoum is relatively safe from an operator's point of view. Vitamin K1 is an effective antidote.

For this operation, brodifacoum was mixed into the bait at manufacture, at a concentration of 20 parts per million (0.002%).

## Managing the threat to non-target species

An important aspect of the eradication strategy was to evaluate and manage as far as possible the risk to non-target species. Experience from previous poison campaigns in New Zealand indicated that there was no significant risk to most species present on Enderby and Rose Islands. However, subantarctic skua (*Stercorarius skua lonnburgi*) and Auckland Island teal (*Anas aucklandica aucklandica*) were cause for some concern. Both species were considered potentially at risk from eating poison baits. Skuas, known scavengers and hunters of rabbits on Enderby and Rose Islands, could be at further risk of secondary poisoning from eating poisoned rabbit carcasses.

All main islands of the Auckland Island group have breeding populations of skuas. Seven pairs on Enderby and three on Rose were recorded breeding in 1991 and 1993. Past observations from other islands indicated that this was less than half the total Auckland Island breeding population. Teal exist on all the large offshore islands in the Auckland Island group. Williams (1986) estimated that the total population was "at least 500 birds". Of these he estimated approximately 50 lived on Rose and 76 on Enderby Island.

As a simple assessment of risk, bait acceptance trials were conducted. Teal in captivity and in the wild on the Auckland Islands were exposed to a non-toxic version of the baits to be used for the poison operation. In both cases the birds showed little interest. Skuas on Enderby Island were also exposed to non-toxic baits. They showed little interest in them, except for two occasions when two birds were seen to eat a few pellets.

Although this was a positive outcome it was not considered conclusive and the decision to undertake the poison operation was made acknowledging there was some risk that was difficult to accurately quantify. This was considered acceptable because the poison operation was to be a one-off event and only a portion of the total Auckland Island population of both species would be exposed. If, in the worst possible scenario, the Enderby and Rose Island populations were completely lost, the islands could be recolonised by birds from other islands in the group.

All bait used during the poison operation was dyed green. This is known to reduce its attractiveness to birds (Caithness and Williams 1971).

## Seasonal timing of the poison drop

Two major factors influenced the timing of the poison operation. It was important that it be done well outside the time when rabbits were breeding, when many young rabbits live underground and are not vulnerable to poison. From ageing data of a sample of rabbits shot on Enderby Island in 1991, Glentworth (pers. comm.) concluded that the breeding season extended from July through to December with a peak around September/October. Observations from other visits to the island indicated that breeding sometimes carried on into January. The second major factor was weather. Because cereal pelleted bait breaks down fairly rapidly in wet conditions, it was desirable to spread it in the driest time of the year. Taking these factors into account, mid February was chosen as the most appropriate time for the main poison operation.

## Bait sowing method

Two applications of bait were made to both islands. This ensured complete coverage, minimising the chance of gaps. It also helped ensure that enough bait was laid in areas of very high animal density and that bait remained available long enough for every rabbit and mouse to be able to consume a lethal dose of poison. Having more than one drop also reduced the risk of failure due to rain. As further insurance, enough resources were on hand for a third poison drop.

Because of the size of the area to be treated and the need to sow bait quickly when weather conditions were suitable, helicopter application was considered the only practical method. Bait was spread using an AS 350 B "Squirrel" helicopter with an under-slung spreader. The spreader was purpose built for this type of operation and had an adjustable aperture which allowed the rate at which bait was being sown to be regulated. It was fitted with a rotary spinner, which threw bait out to 20 m either side of the spreader. This gave a 40 m wide strip (or swath) of bait coverage for each pass of the helicopter. Parallel flight lines were flown north to south across the islands 35 m apart to ensure there was an overlap between swaths. To help with this on Enderby Island, one person walked along a line running east to west across the island marking 35 m intervals measured with a hip-chain. This gave the helicopter pilot a reference point for each pass. Using this method, accurate coverage was achieved during both poison drops. On the much smaller Rose Island this was not necessary, as it was easier to keep track of where bait had been spread.

## Phase one – the poison drop

The services of a professional weather forecaster in New Zealand were used to help choose a relatively dry and settled period of weather for the bait applications. We made contact via radio and were able to receive forecasts for the Auckland Islands area when needed.

The first application of bait was sown on 15 February 1993, and the second, after having been delayed slightly by weather, was 18 days later on 5 March. The applications were spaced so that most rabbits poisoned from the first had died before the second was applied.

Bait was applied at 5 kg/ha over the whole of Rose Island on both drops. On Enderby Island the rate was the same, with the exception of 100 ha of heavily rabbit-infested country. This area was treated at 10 kg/ha during the first drop. On the second drop only 20 ha were treated at this increased rate.

During both applications on Enderby Island, special care was taken to ensure bait fell on all areas where mice might live. These included small ledges on cliff faces and small beaches and rock platforms at the base of coastal cliffs, which wouldn't have been treated in a campaign against rabbits only. Bait was also sown at a rate high enough for confidence that all mice would have access to a lethal dose of poison.

As a check that bait was being sown at the correct nominated rate, Enderby Island was divided into 100 ha blocks. As each block was completed, the quantity of bait sown in that block was checked.

Less than 1 mm of rain was recorded at Enderby Island for the 10 days after the first bait drop and only 14 mm fell in the seven days after the second. This was not considered enough to reduce the effectiveness of the bait in any way.

## Phase two – the follow up

From one week after the second drop until leaving Enderby Island eight weeks later on 8 May, and during the second five week visit to the islands one year later in Jan/Feb 1994, the field team (assisted by a trained rabbit-tracking dog) concentrated on locating and destroying any rabbits remaining after the poison operation. The dog was the most effective method used in this part of the operation. The dog found and followed rabbit scent, generally flushing rabbits from cover when they would either be shot or chased down burrows from where they were dug up and destroyed. Occasionally, the dog caught a rabbit before it could get to a burrow. This was especially so for young animals. On some occasions the dog would consistently follow rabbit scent in a particular area but we would not be able to find the rabbit and would need to visit the area repeatedly before accounting for that individual. In this way some rabbits were hunted over a period of up to 10 days before finally being destroyed. By this process we became familiar with their movement patterns and found that these rabbits ranged within discrete areas, which in some cases could be up to 25 ha.

The dog also gave us a high degree of confidence in establishing the absence of rabbits. For example, once we had thoroughly searched an area a number of times with the dog and found no sign we could be reasonably confident that there no were rabbits present.

Spotlighting was another method used to find and destroy rabbits. Teams armed with a shotgun and spotlight (operated from a 12 volt battery) would hunt on calm, dry nights when conditions were considered most favourable for rabbit activity, or if a known rabbit had not been caught during day hunting expeditions. Although this was not nearly as productive as hunting with the dog, some rabbits were destroyed using this method.

Traps were used on only one occasion. The last rabbit on Rose Island proved very difficult to catch using the methods outlined above. The dog could consistently find and track its scent but because of heavy cover in the area where the rabbit was living it proved impossible to shoot or chase to ground. Spotlighting also proved ineffective. As a last resort six "Lanes Ace" leg-hold traps were set in the area

it was known to be using. This rabbit was caught on the second night the traps were set.

In addition to these methods many hundreds of hours were spent systematically and meticulously searching both islands for rabbit sign. Once sign had been located we never failed to eventually find and kill the rabbit that had left it.

During this phase the team kept a careful watch for any sign of mice surviving on Enderby Island.

## RESULTS

### Impacts on rabbits and mice

On Enderby, the first dead rabbit was found four days after the initial poison drop. From then on the rate of mortality steadily climbed, to peak at around 10 days after the drop. Rabbits continued to die from the effects of the first drop right up to the point where the second drop was sown. At this point, from casual observation, mortality appeared to have reached in excess of 90%. After the second application of poison, most of the remaining rabbits quickly disappeared and by mid March live rabbits were extremely rare (Fig. 4). Rose Island was not monitored as closely as Enderby before and during poisoning, but it seems likely from observations made during regular visits that the kill rate there closely resembled that on Enderby.

From mid March to early May 1993, 22 live rabbits were found and killed on Enderby and 12 were found and killed on Rose. Some of these animals showed obvious symptoms of poisoning and would probably have died, given time. However, approximately 70% of the survivors (25 animals), showed no obvious sign of having taken poison. In each of these cases we know that the animal had access to bait because we had either checked the area where it was living for bait coverage soon after the poison drop or there was still sign of bait present when the animal was found. Without having samples from these rabbits analysed for traces of brodifacoum it is impossible to be certain, but it seems likely that at least some of these animals avoided eating the bait.

The last rabbit was caught on Enderby on 12 April, and on Rose on 27 April 1993. This gave a further four weeks on Enderby and two weeks on Rose for careful searching, during which time there was no sign of live rabbits. During a visit to the islands specifically to search for rabbit sign in Jan-Feb 1994, no indications of rabbit presence were found. Following this, a careful search of both islands by party members of expeditions stationed on Enderby over the summer of 1994-1995 also failed to find any sign of rabbits. It would appear that rabbits were eradicated during the 1993 expedition.

Several mice showing obvious signs of poisoning were found within three days of the first application of bait on Enderby Island. From then on, all sign of live mice on the island quickly disappeared, and the remains of dead mice were commonly seen during searches of the island over the remainder of the 1993 trip. No mouse sign has been seen on the island since then despite a careful search for sign during the 1994 trip and on all subsequent visits to the island. It appears that mice have been eradicated from Enderby Island.

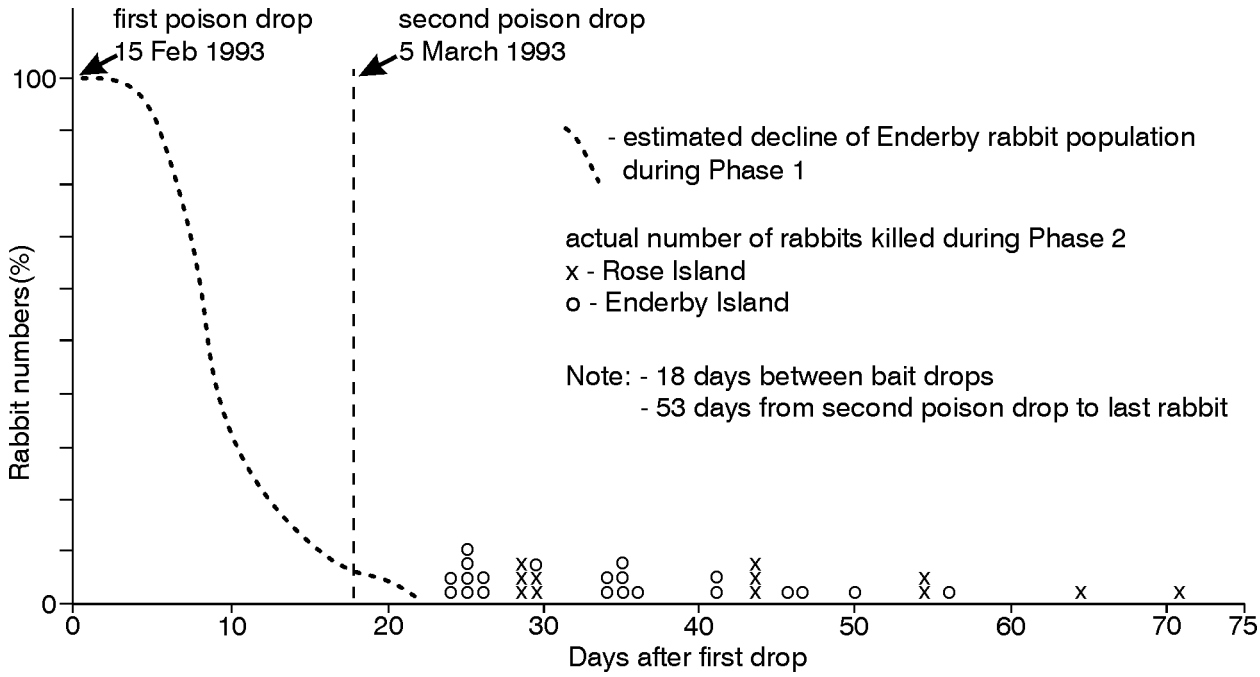


**Fig. 4 Estimated decline of rabbits during Phase 1 of the operation on Enderby Island (dotted line) and the number of rabbits killed during Phase 2 for Rose (x) and Enderby (o) Islands shown with one symbol for each animal killed.**

## Impact on non-target species

Four Auckland Island teal carcasses were found on Enderby and three on Rose Island in the two months following the poison operation. Although there is no direct evidence that these birds died from eating poison, it seems likely that at least some of them did. Despite these deaths, live teal were encountered frequently on both islands after the poison operation in 1993 and during the 1994 visit. From casual observation there appeared to be little difference in frequency of encounters before and after the poison operation. It therefore appears that although some teal were poisoned, the total lost was relatively few.

Approximately two thirds (40 birds) of the Enderby and Rose Islands skua population died during the poison operation, apparently from eating poisoned bait. We knew skuas had eaten poison because the green dye used in the bait was visible in their droppings. Although the possibility of a loss had been predicted, the fact that the majority of birds were poisoned from eating bait, rather than from secondary poisoning, was unexpected. About 20 skuas were still seen around both islands by the time we departed at the end of the 1993 trip. During the 1994 trip the numbers seen were about the same or slightly greater though only one pair was found breeding on each island. Since 1994 the skua population on both islands has recovered to near pre-eradication levels. Fifty-two birds including five breeding pairs were counted on Enderby in the summer of 2000-2001 and two pairs were found breeding on Rose.

In addition to teal and skua deaths, about 10 blackbirds (*Turdus merula*) were also found dead or showing obvious signs of poisoning following the poison operation. Blackbirds were still seen frequently later in the trip and in the following year. The impact on the local population was apparently not great. Although the risk to blackbirds was identified during planning for the poison operation, it was not a serious concern because they are a species introduced to the New Zealand region, common in all parts of New Zealand.

## DISCUSSION

The results of the initial poison campaign were remarkably successful. Of the estimated 5000-6000 rabbits present on Enderby Island, over 99% were destroyed during the first phase of the eradication programme. Nevertheless, a significant number of rabbits apparently avoided eating bait and were destroyed during the follow-up phase. This also occurred during the eradication programmes on Round and Whale Islands (Merton 1987; Jansen 1993). This bait avoidance is particularly interesting in the case of the Enderby and Rose Islands rabbit populations, which have existed in almost complete isolation from human contact for over 100 years. Bait avoidance has clearly not developed through any direct experience of poison or baiting regimes but rather may be an innate neophobia that occurs naturally in some rabbit populations. This has implications for any similar rabbit eradication programmes and emphasises the importance of having an adequate follow-up phase built into the programme to account for the last few animals.

The dog played a key role during the follow-up phase on Enderby and Rose Islands, and was by far the most effective method used to find and destroy rabbits. Without the dog the programme would certainly not have reached its successful conclusion so quickly. Another factor contributing to the success of the second phase and the overall goal of eradication was the experience and dedication of the team on the island. Without these two factors, the programme would probably have had to continue for at least one more year and may never have reached its ultimate goal of eradicating rabbits.

The absence of any signs of mice on Enderby Island since late February 1993 suggests that they were eradicated by the poison campaign during the first phase of this programme. The Department of Conservation (DOC) has remained cautious about this outcome until now because mice can be very difficult to detect at low densities, especially on an island the size of Enderby. However, scientific parties have worked on the island and lived in the established camp at Sandy Bay where mice were common pre-eradication, for periods in excess of six weeks every summer since the eradication. They have failed to find any sign of mice at the camp or on any other part of the island. The chance of mice existing on the island and escaping detection for so long now seems to be very slight indeed.

One of the often-difficult aspects of planning and running eradication programmes is predicting and managing the impact on non-target species. In almost all cases where traps or poison are used there will be some cost to non-target species. This needs to be balanced against the overall benefits gained from pest eradication. Within New Zealand there have been over 110 successful eradications of introduced animals from islands (Veitch 1994). In almost every instance the original biota of the island and their natural ecosystems have benefited, often spectacularly so. This includes many non-target species that initially suffered during the eradication programme.

As a general rule, so long as the impacts on non-target species are not irreversible, the benefit to the island in the long term will far outweigh any short-term losses. Bearing this in mind, care needs to be taken that any measures introduced to reduce the impact on non-target species do not compromise the chances of successful eradication of the target species. These principles were applied during the planning for this eradication, and in the case of skua and teal we were prepared to sustain greater losses than actually occurred.

Although the possibility of some skua losses had been predicted, the fact that so many birds died from eating bait was unexpected. Trials had indicated skuas showed little interest in the type of bait used for this operation. How-

ever, over half the skuas on both islands were observed to have eaten bait within 10 days of the first poison application. There were two main differences between bait trials and the poison operation. During the bait trials baits were either un-dyed or were dyed red with Rhodamine B. During the poison operation baits were dyed green. The other difference was that during the poison operation baits were available over a much wider area and for a longer period than during the bait trials. Perhaps, during this time some birds learned that baits were palatable and this behaviour was passed through the population. Most birds ignored baits until they had been available for at least several days and some birds appeared to never eat baits.

Some changes on Enderby and Rose Islands were obvious almost immediately following the removal of rabbits. Many palatable plants that had continually suffered from browsing pressure are now showing spectacular signs of recovery. The predominant tussock, *Poa litorosa*, which had been severely restricted in distribution on Enderby, is now advancing quickly and invading many areas of the herbaceous sward. The megaherbs *Stilbocarpa polaris* and *Anisotome latifolia* which had previously been restricted to cliff areas are found much more widely over both islands and scattered plants of *Pleurophyllum criniferum* (not recorded on Enderby Island for many years) can now be found.

Several mammal and bird species have already, or are likely to, benefit from the absence of rabbits. The death of New Zealand sea lion pups in rabbit burrows on Enderby Island has become much less of a problem as the disused burrows collapse or are filled in. Species like Auckland Island teal and Auckland Island snipe (*Ceonocorypha aucklandica*) that are vulnerable to avian predators (such as skua and falcon) are likely to benefit as more vegetative cover and resulting habitat becomes available to them. This is especially so for Enderby, where Williams' (1986) estimate of 76 teal on the 700 ha island is compared with his estimate of at least 130 birds on neighbouring 54 ha Ewing Island, where the vegetation cover is much more intact. Yellow-eyed penguins (*Megadyptes antipodes*) which nest on both islands, may benefit as the quality of nesting cover improves. Auckland Island rail (*Rallus pectoralis*), a rare Auckland Island endemic, very vulnerable to introduced and avian predators and presently known only from Adams and Disappointment Islands, may in time colonise or could be introduced to these islands as habitat improves.

Although it is accepted that modified habitats may not return to their pristine condition after introduced animals have been removed, it is expected that these two islands will reach a condition closely resembling it. This could take longer than 50-100 years and may require the careful management of some weed species in the interim.

Despite having to operate in a very remote and sometimes difficult environment, the eradication programme was very successful and ran smoothly. There were a number of important factors that contributed to this:

- everyone involved had a single clear objective: eradication of rabbits;
- total dedication to the objective by all staff involved and by the Department of Conservation in general;
- careful planning which acknowledged that once on the island the team would have to operate in almost complete isolation from mainland support. This meant planning for many different eventualities and having flexibility in the programme and the resources on hand to deal with them;
- good technology, including a very efficient and potent toxin, pre-manufactured bait which was easy to handle, durable, and highly palatable to the target species, and the use of helicopters which made the delivery of bait to large and inaccessible areas fast and accurate;
- adequate resources, including funding and the ability to bring in suitably skilled and experienced staff.

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