# The history of the aerial application of rodenticide in New Zealand

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**Abstract** Following the incursion of rats (*Rattus rattus*) on Taukihepa (Big South Cape Island; 93.9 km²) off southern New Zealand in 1963, and the subsequent extirpation of several endemic species, the New Zealand Wildlife Service realised that, contrary to general belief at the time, introduced predators do not reach a natural balance with native species and that a safe breeding habitat for an increasing number of 'at risk' species was urgently needed. Offshore islands offered the best option for providing predator free habitat but there was a limited number of predator-free islands available and most were very small. Eradicating rodents on larger islands to provide a wider range and greater area of habitats was required and hand treating these larger areas using trapping and hand application of toxicants, the only methods available at the time, proved problematic and often impossible. Helicopters had been used to distribute bait for the control of rabbits and brushtail possums in the past but eradication of any particular predator species was considered 'not feasible'. The development of a GPS-based aircraft guidance system, a suitable bait product, specialised bait delivery systems and second-generation anti-coagulant toxicants changed that. Now islands as large as South Georgia (3,900 km²) have been treated using this method.

**Keywords:** aerial application, brodifacoum, eradication, helicopter, *Mus musculus* – house mouse, *Rattus exulans* – Pacific rat, *Rattus norvegicus* – Norway rat, *Rattus rattus* – ship rat

## INTRODUCTION

New Zealand's terrestrial flora and fauna evolved in isolation from mammalian predators leading to many species being highly susceptible to any ground-based predators that hunt by smell and sight (e.g. Tennyson & Martinson, 2006). Since the arrival of humans, this unique environment has suffered from the deliberate or accidental introduction of a range of species that have decimated native biodiversity. This includes four species of rodent, Norway rat (*Rattus norvegicus),* ship rat *(R. rattus),* Pacific rat or kiore *(R. exulans*) and house mouse (*Mus musculus*), which continue to have a devastating impact on New Zealand's native flora and fauna (King, 2005).

Polynesians arrived in New Zealand bringing with them the Pacific rat or kiore. The rats, along with kuri or native dog (*Canis familiaris*), were brought for food and clothing and led to the first wave of extinctions in New Zealand (Tennyson & Martinson, 2006). In 1770, James Cook mentions vermin in his journals and this may refer to Norway rat (Innes, 2005). House mice had arrived in New Zealand by 1830 (Ruscoe & Murphy, 2005). Ship rats were introduced with early European settlers between 1860 and 1890 and had both cumulative and additional impacts to the rodent species that were already present (King, 2005; Tennyson & Martinson, 2006).

Invasive species have caused ecological problems around the world since humans started exploring but it was in New Zealand, where biodiversity loss was obviously due to introduced predators (Tennyson & Martinson, 2006), that organisations began to consider ways to minimise these impacts. It was not until the mid-1990s that technology advanced to a stage where this human induced disaster could be offset on any significant scale (Towns, et al., 2013).

This paper outlines the key events that led to the development of a rodent eradication tool used around the world today and discusses the role played in this process by the New Zealand agricultural aviation industry.

## RECOGNITION OF THE DAMAGE RODENTS COULD DO TO NEW ZEALAND WILDLIFE

The ship rat invasion of Taukihepa (Big South Cape Island; 93.9 km²) in the early 1960s and the extinction of three species of endemic vertebrates sent shock waves through conservation circles (Bell, et al., 2016). A fourth species was saved only by transferring to it a nearby predator-free island. This disaster led to an increased interest in the ecology of rodents and their impact on native species as well as ways to control or eradicate them along with other introduced predators (Towns & Broome, 2003).

## ERADICATION TOOLS AND ADVANCES

### Early application of aircraft in New Zealand agriculture

Demobilised World War II pilots in New Zealand began an industry applying fertiliser and grass seed to hill country and established the skills to fly accurate parallel swath patterns. The spread of fertiliser and seed initially used fixed wing aircraft as outlined by Alexander & Tullett (1967), but the skills were later transferred to the use of helicopters.

The skill and experience of the pilots is a crucial component of any aerial baiting operation. In addition to having experience with all the systems that are to be used

Fig. 1 Auster aircraft loading rabbit bait, MacKenzie Basin 1951.

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in the operation (e.g. helicopter, bucket, GPS etc.), they are often required to fly under adverse conditions such as during poor weather, across islands with challenging topography and frequently a high risk of bird strikes. Pilots are expected to fly accurate lines in spite of these challenges whilst also monitoring the bait flow out of the bucket. It is highly desirable that the pilots are involved in the planning for an eradication as they can identify both risks and opportunities associated with the bait application.

### The establishment of the Department of Conservation

The establishment of the New Zealand Government's Department of Conservation (DOC) out of the Wildlife Service, Forest Service and Department of Lands and Survey brought the various government agencies charged with protecting biodiversity under one management regime and allowed better focus on prioritising 'endangered species' programmes, including predator removal. The Department of Conservation was able to provide the financial and political support necessary to carry out this work. This was especially so with the larger projects such as Campbell Island (113.3 km²) in the New Zealand sub-Antarctic. Current operations now follow the international trend of joint venture or partnership operations with Non-Government Organisations (NGOs) and private conservation trusts.

## IMPROVEMENTS IN TECHNOLOGY

### Development of toxins

On the mainland, compressed grain bait (pellets) suitable for dispersal through a mechanised spreader bucket (Fig. 2) were also laced with 1080 and phosphorus to target brushtailed possums (*Trichosurus vulpecula*) (Bill Simmons pers. comm.). Prior to this, aerial bait application had been predominantly diced carrot or grain.

The development of the second-generation blood anticoagulant toxicant brodifacoum in England in the mid-1970s provided a toxicant suitable for large-scale rodent eradication (Dubock & Kaudeinen, 1978). The delayed action of the anticoagulant toxicants meant that rodents would consume a lethal dose of toxicant before showing any symptoms, thus eliminating the risk of bait avoidance. Brodifacoum also has the ability to kill a rodent with a single feed, compared to the first-generation anti coagulants that required multiple feeds over several days. Brodifacoum is currently registered in over 40 countries in the form of over 100 separate registrations covering different formulations or product forms (Kaudeinen & Rampaud, 1986).

**Fig. 2** Compressed cereal bait impregnated with brodifacoum.

**Fig. 3** Purpose built eradication bucket 2001.

### Development of bait spreading equipment

Various New Zealand agricultural helicopter companies had been developing underslung cargo hook-mounted spreader buckets for the application of fertiliser and seed. By 1980, these spreader buckets had been modified to spread toxin-laced chopped carrot and cereal-based pellets for the control of rabbits and possums (Peter Garden, unpublished data).

Purpose-built bait-spreading buckets have continued to be developed (Fig. 3), and these now allow for a consistent swath width and density of bait application on a large scale. Buckets have been repeatedly refined to provide a wider bait swath and, most importantly, the addition of an internal deflector to direct bait just out one side minimising any bait that may go into the marine environment as well as being able to treat cliffs. Additional improvements including linking the bait flow to the flight track recording system are currently being developed.

### Development of guidance and data recording equipment

Various methods to assist pilots in following straight lines have been tried. One of these, the Decca Navigation System, was used on forestry spraying operations as early as 1980 and used in a possum control operation on Rangitoto Island in 1990. Another method trialled was using reciprocal compass headings at the end of each run. This required the pilot to make calculations using compass variation, deviation and cross wind headings.

The United States military developed a constellation of global orbiting satellites in the late 1970s to provide very accurate navigation information. The Global Positioning System (GPS) relies on highly accurate time and position information transmitted by these satellites to receivers on the ground or in aircraft. The receivers use triangulation to compute three-dimensional position, direction and speed of travel information. To preserve security of this information, deliberate errors were factored in and the corrections for these errors were only available to those with security clearance to use them. This error factor was known as 'selective availability'. The civilian world was keen to access this information and several companies developed simple navigation devices that could be used for guidance within the expected error range. The error range was not consistent but was never much more than a few hundred meters, which was acceptable to support other navigational equipment. However, to be an effective guidance tool for aerial application this error could be no more than one or two metres. In 1993, attempts were made to use GPS for guiding bait spread onto Cuvier Island, but a suitable satellite triangulation system at that time was not available (D.R. Towns, pers. comm.).

In 1995, an American avionics manufacturer, Trimble Navigation, set up a facility in Christchurch New Zealand with the specific purpose of developing systems for use in aerial agricultural application that could meet the very stringent accuracy requirements of that industry. The system required the use of a 'base station' that recorded satellite signals transmitted over time and calculated the errors. The corrected information was then transmitted to the aircraft by radio telemetry.

By 2000, the US military had switched off the 'selective availability' function so the use of base stations was no longer necessary. More recently, a New Zealand based company, TracMap Ltd™, has developed a system designed specifically for aerial application – for the distribution of both agricultural products and bait (Fig. 4).

The first island eradication where GPS guidance equipment was successfully used was on Tiritiri Matangi (1.7 km²) in 1993 (Veitch, 2002d).

## ERADICATION HISTORY

### Early aerial application of toxicants

Rabbits (*Oryctolagus cuniculus*) were introduced for sport and as supplementary food for settlers in the 1830s (King 2005). However, the animals soon developed into plague proportions, particularly in the drier inland areas where they contributed to significant land erosion (King, 2005). Systems were developed for the aerial application of toxicants to control rabbits using fixed wing aircraft (Fig. 1). This was predominantly using either carrot pieces or grain laced with the toxin 1080 (sodium monofluoroacetate).

The first recorded island rat eradication in New Zealand was the removal of Norway rats by hand baiting from Maria Island (1 ha), Noises Islands, in 1960 (Towns & Broome, 2003). as the first in a series of unintended rodent eradications when control had been the expected outcome.

**Fig. 4** TracMap™ GPS guidance equipment fitted to South Georgia Heritage Trust aircraft,2015.

The first use of bait stations was by Ian McFadden on Rurima Island (0.045 km²) in 1983, using maize laced with the anticoagulant bromadialone and the same product was used successfully on Korapuki Island (0.18 km²) in 1986. Both campaigns were against Pacific rats (and rabbits on Korapuki, McFadden & Towns, 1991). Between 1986 and 1988, commercially available Talon™ (brodifacoum) wax blocks in bait stations were used to eradicate Norway rats from Hawea (9 ha) and Breaksea (1.70 km²) islands in Fiordland (Thomas & Taylor, 2002). While this type of technique has been used on islands as large as 31 km² Langara Island, Canada (Taylor, et al., 2000), the usefulness of this method is limited by topography of the target island and logistical difficulties associated with ensuring complete coverage of the island.

### Early use of aircraft targeting rodents on islands

In 1986, Moutohora Island (1.43 km²) in the Bay of Plenty was the first island in New Zealand to be treated using aerially distributed toxic bait (Talon™ 20P, active ingredient brodifacoum) to target rabbits using a fertiliser spreading bucket. As an unplanned side effect, Norway rats were also removed as part of this operation (Jansen, 1993).

The first attempt at aerially distributing rodenticide targeting rats in New Zealand occurred on the Mokohinau Islands (0.73 km²) in the Hauraki Gulf in 1990 (Towns & Broome, 2003). This operation was carried out using a 'monsoon' firefighting bucket to spread Talon™ 20P and resulted in the removal of Pacific rats. However, it was identified that the bait spread was concentrated along a narrow swath, due to the bucket not having a spinner to spread the bait out, and hand spreading was required to fill in the gaps (McFadden & Greene, 1994).

Between 1991 and 1993 a partnership was developed between DOC and ICI Crop Care, to improve the durability of Talon™ 20P (brodifacoum) and to license the product for aerial spread against rodents. An efficient means of spreading the baits also needed to be developed. By 1993, Ian McFadden of DOC and Tony Monk of Heletranz had developed a bait bucket with spinner, for use against rodents on offshore islands. The bucket was used to spread Talon™ 20P to target Pacific rats on Cuvier Island (1.81 km²) in 1993 (Towns & Stephens, 1997).

### Increasing the scale

The first large scale aerial application operation specifically targeting rodents (Norway and Pacific rats) was carried out on 19.65 km² Kapiti Island (Fig. 5) off the south-west side of the North Island, New Zealand (Miskelly & Empson, 1999). The operation succeeded in removing both species. This island was four times larger than any previously attempted (Broome, 2009).

**Fig. 5** Mechanical loading of bait for Kapiti Island, 1996.

**Fig. 6** Hand loading bait on Codfish/Whenua Hou, 1997.

**Fig. 8** Bait spreading on Mokonui Island, off Stewart Island, 2006.

Pacific rats were eradicated from Putauhina Island (1.41 km²) and Raratoka Island (0.88 km²) off southern Stewart Island in 1997 in the lead-up to rodent eradication on Whenua Hou (Codfish Is; 13.96 km²). (McClelland, 2002) Although these islands had significant conservation values in their own right, the removal of rats was largely to establish procedures and issues for the treatment of Whenua Hou in order to provide a predator free environment to establish a kakapo breeding base (Merton, et al 2006)

In August 1998, two applications of brodifacoum-laced compressed cereal bait were aerially applied to 13.96 km² Whenua Hou (Fig. 6) to remove Pacific rats (McClelland, 2011). The Kapiti project used two applications and this has become the standard methodology for aerial bait applications for eradicating rats on islands worldwide, with modifications as required for each island.

Tuhua/Mayor Island (12.83 km²) in the Bay of Plenty, New Zealand was successfully treated for the removal of Norway rats and Pacific rats in 2000, largely to test the methods required against rats and cats on the much larger and more remote Raoul Island in the Kermadecs (Williams & Jones, 2003).

Campbell Island followed on from the success of the Kapiti and Codfish/Whena Hou eradication programmes. DOC embarked on a very ambitious plan to eradicate Norway rats from this 113.31 km² island, 700 kilometres south of mainland New Zealand. The logistics of this project far exceeded anything that had been contemplated previously and required a rethink on how such operations could be streamlined to make them logistically and financially feasible. The resulting operational plan called for a single application of just 50% of the standard bait rate. This was a substantial risk but the GPS navigation and spreader bucket technology and experienced pilots gave planners confidence in being able to achieve complete coverage. A 600 ha trial involving the aerial application of non-toxic bait with a biomarker was carried out to test the proposed methodology before the full operation (Fig. 7) was started. (McClelland, 2011). Over the period 2000 to 2008, more than a dozen islands around the New Zealand coastline were treated including: Raoul (29.38 km²) in the Kermadecs (Ambrose, 2006; Little Barrier (30.83 km²) in the Hauraki Gulf (Griffiths, et al., 2019); Bench (1.21 km²) and Pearl (5.12 km²) off Stewart Island (Brent Beaven pers. comm.); Coal (11 km²) Preservation Inlet, (Brown, 2013); Pomona (2.62 km²) and Rona Islands (0.6 km²) (Shaw & Torr, 2011). Notable during this period was the Rakiura Titi Islands restoration project (McClelland, et al., 2011) which included Mokonui (0.86 km²) (Fig. 8) and Taukihepa/ Big South Cape (9.39 km²) islands. Managing non-target risks, multi-species eradications and reinvasion issues are all now part of the planning process and this culminated in the Rangitoto/Motutapu project 34.81 km² in 2009 that targeted seven species of introduced mammals including the four species of rodent (*M. musculus, R. rattus, R. norvegicus, R. exulans*). (Griffiths, et al., 2015).

Mice removal from 20.02 km² Antipodes Island 850 km south-east of Bluff (New Zealand) occurred in winter, 2016 (Horn & Hawkins, 2017) (Fig. 9). Success has been confirmed.

**Fig. 7** Spreading bait on cliffs, Campbell Island, 2001.

**Fig. 9** Mouse eradication operations Antipodes Island, 2016.

## INTERNATIONAL PROJECTS

### Exporting the technology

Because of the concern for the critically endangered Seychelles magpie robin *(Copsychus sechellarum),* an operation to carry out the eradication of Norway rats from Denis (1.43 km²), Frigate (2.19 km²) and Curieuse (2.86 km²) Islands in the Seychelles was completed in June and July 2000 (Merton, et al., 2002).

The same basic technique, usually using New Zealand-made spreader buckets and often with experienced New Zealand pilots, has been and is used to eradicate rodents on islands worldwide. Methods are modified for each island with alterations made to sowing density, number of drops, timing between drops etc., To date rodents have been eradicated from more than 300 islands using this technique, making it the most widely used and most successful technique for rodent eradications compared to bait stations, hand broadcast or traps. (Howald, et al., 2007). Whereas there are still some situations where the other techniques are the most suitable option, e.g. on islands where it is not practical to use aerial eradication methods it has allowed islands that could never previously have been considered for eradication programmes to be treated successfully. The largest island worked on to date is 3900 km² (1070 km² treated) South Georgia Island in the sub-Antarctic (Black, et al., 2013), which had Norway rats and an isolated population of mice treated in three phases over a five-year period from 2011 to 2015. Other successful international eradications using this methodology include Macquarie (128 km²) where rabbits, ship rats and mice were eradicated in 2012 (Parks and Wildlife Service, 2014) and Rat Island/Hawadax (10 km²) in the Aleutians where Norway rats were eradicated in 2008 (Buckelew, et al., 2011).

Aerial distribution of bait has now been successfully used for the eradication of rodents in more than ten countries including Australia, USA, Canada, Mexico, Japan, Italy and several smaller Pacific Island nations.

## CONCLUSION

The aerial dispersal of rodenticide has been a 'game changer' allowing large and geographically challenging islands and tracts of land to be treated quickly and efficiently. The advent of GPS guidance and recording equipment and purpose-built distribution systems (spreader buckets) has given project managers confidence that a lethal dose of toxic bait can be delivered into each home range of the target species, maximising the chances of eradication.

Many organisations and islands around the world have benefited from the developments carried out in New Zealand since the availability of second-generation anticoagulant toxicants. Now NGOs and Government departments in all corners of the globe are using this information to carry out their own projects. These in turn are now providing feedback to advance the knowledge base needed to carry out ever more complex and challenging projects.

While aerial application of toxic bait has been a major advancement in habitat restoration, ground based techniques – bait stations and hand broadcast – are still used where relevant. These methods tend to be used on smaller, more accessible islands as well as around dwellings on inhabited islands during aerial operations. However, the ability to treat large areas in a short space of time and the lower overall cost per hectare of treatment make aerial application a valuable tool in the continuing fight against invasive predators. The scale of islands that may be treated in the future is limited only by the supporting logistics, funding and political support.

The fact that much of the aerial application expertise resides in New Zealand has more to do with the incremental development of systems, procedures and technology that has occurred here over the past 30 years. As the baiting pilot has the final control over the success of any project, it is vital that they have complete commitment to that end. Project managers should involve the likely application pilot(s) at an early stage to ensure this commitment.

Many challenges still exist, especially in tropical and subtropical regions where success rates have been lower, and there is room for continued development of equipment and systems, but the use of this method of distribution of rodenticide will continue into the foreseeable future. An increasing number of inhabited islands is now being treated and this brings a new series of challenges for project managers. Numerous issues that do not need to be considered on uninhabited islands come into play, making these operations considerably more complex.

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