



## Restoration of New Zealand subantarctic islands

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**Abstract:** New Zealand manages five island groups in the Southern Ocean New Zealand subantarctic region: The Snares (Tini Heke), Bounty Islands, Antipodes Islands, Auckland Islands (Motu Maha or Maungahuka) and Campbell Island / Motu Ihupuku. Charted by Europeans in the late 18th and early 19th centuries, their preservation commenced in the early 20th century and restoration in the late 20th century. Since 1984, eradications of six introduced mammal species (cattle *Bos taurus*, sheep *Ovis aries*, goats *Capra hircus*, rabbits *Oryctolagus cuniculus*, Norway rats *Rattus norvegicus*, and mice *Mus musculus*) across five islands (Campbell, Antipodes, Auckland, Enderby and Rose) have taken place. The only introduced mammal species remaining in the New Zealand subantarctic region are pigs (*Sus scrofa*), cats (*Felis catus*) and mice on the main Auckland Island. Building on previous eradication work, from 2018 to 2020 the Department of Conservation undertook research and development to determine the feasibility and cost of a multi-species eradication programme on Auckland Island. The outcomes of the research programme not only inform eradication on Auckland Island, but have wider applicability to other eradication programmes throughout the Southern Ocean.

**Keywords:** Auckland Island, cat, conservation, eradication, island, mammal, mice, pig, restoration, subantarctic

### Introduction

The New Zealand subantarctic region lies between the Antarctic and Subtropical Convergences and contains over 25 islands across five island groups: The Snares (Tini Heke), Bounty Islands, Antipodes Islands, Auckland Islands (Motu Maha or Maungahuka) and Campbell Island / Motu Ihupuku (group) with a total land area of over 70 000 hectares (Fig. 1). All five groups are Nature Reserves, and the latter four are also marine reserves. Together they harbour over 400 plant and animal species, more than 100 of which are endemic to the region. The entire region is managed by the New Zealand Department of Conservation (Roberts 2007) and inscribed as a UNESCO World Heritage Area containing some of the world's least-modified islands (Claudino-Sales 2019).

The islands were visited by Polynesians in the 13th century (Anderson 2005) and later re-discovered by Europeans from 1788 to 1810. Although uninhabited today, the islands have a rich history of exploitation of marine mammals (Richards 2010); attempts at settlement (Fraser 2014) and agriculture (Dingwall 2009); and deliberate or accidental introductions of species to the islands (Russell et al. 2020a). All these impacts have changed the ecological trajectories of the islands, while forecast impacts from climate change and tourism present emerging threats (Stewart et al. 2017). Protection of the islands as Nature Reserves commenced from 1910.

### Restoration

Since their discovery a total of eleven species of mammals have been introduced to the New Zealand subantarctic islands (Table 1), establishing enduring populations on six of them. Deliberate permanent removal of the introduced mammals began in the 1970s with removal of sheep (*Ovis aries*) from Campbell Island (Brown et al. 2022b), followed in the 1980s with removal of cattle (*Bos taurus*) from Campbell Island (Brown & Cox 2022b) and in the 1990s with the removal of cattle on Enderby Island (Brown & Cox 2022a). Goats (*Capra hircus*) were also targeted on Auckland Island around this time as they appeared to occupy a limited area around their point of release and presented a manageable unit to eradicate (Brown et al. 2022a). Rabbits (*Oryctolagus cuniculus*) on Enderby Island presented the next logical step in eradicable invasive mammals and with mice (*Mus musculus*) were successfully eradicated in 1993 (Torr 2002). Due to their long isolation, many of these Auckland Islands mammal breeds had unique properties that led to rescue operations prior to eradications, followed by breeding programmes on the New Zealand mainland (Trotter & Willis 2022).

By the mid-1990s rodent eradication attempts on islands around New Zealand were increasingly successful, and new technologies like aerial poison bait application using navigational guidance were being adopted (Russell & Broome 2016). This led to the removal of Norway rats (*Rattus*



**Figure 1.** New Zealand and its subantarctic region.

*norvegicus*) from Campbell Island in 2001 (McClelland 2011), at the time five times larger than any rodent eradication attempted in New Zealand and for a decade the world's largest island to be successfully rid of rats. The remaining invasive mammals on Antipodes Island and Auckland Island presented formidable challenges of cost and feasibility. It was not until 2016 that mice were finally removed from Antipodes Island (Horn et al. 2019), and mice, pigs (*Sus scrofa*) and cats (*Felis catus*) still remain on Auckland Island. Where introduced mammals have been eradicated from these islands, flora and fauna have recovered dramatically (Miskelly & Fraser 2006; French et al. 2020; Russell et al. 2020b; Brown & Cox 2022a; Brown et al. 2022b; Horn et al. 2022a).

### Pest Free Auckland Island

Auckland Island (45 891 ha) is the fifth largest island in New Zealand and the largest uninhabited island. The Auckland

Islands group is the most biologically rich of the New Zealand subantarctic islands with high endemism among its bird fauna (Miskelly & Symes 2020). Introduced pigs, cats and mice have inflicted severe detrimental impacts on biodiversity over two centuries (Russell et al. 2020a). Auckland Island is the only island in the New Zealand subantarctic region that remains inhabited by introduced mammals (Russell et al. 2020a). The removal of pigs, cats and mice would complete the programme of mammal eradication for the World Heritage Area and remove the substantial risk of mammals invading nearby Adams Island (9693 ha), New Zealand's largest naturally pest-free island. From 2018 to 2020 the New Zealand Government invested NZ\$3 million in the 'Maukahuka: Pest Free Auckland Island' programme. This programme undertook research to inform a feasibility study for the eradication of the remaining three introduced mammal species on Auckland Island.

This project is the first time that the eradication of all three mammals has been proposed in one logistical operation. Each of pigs, cats, and mice present unique challenges for

**Table 1.** Terrestrial mammals introduced to the New Zealand subantarctic region presented in order of disappearance on each group.

Group	Species	Introduction	Status	Reference
Bounty Islands	None			
Snares Islands	Goats	1890	Died out	Cass (2014)
Campbell Island / Motu Ihupuku	Goats	1865	Died out	Brown et al. (2022b)
	Mice	prior to 1931	Died out	Taylor (1978)
	Cattle	1902	Eradicated (1984)	Brown and Cox (2022b)
	Sheep	1865	Eradicated (1970–1991)	Brown et al. (2022b)
	Cats	c. 1904	Died out	Brown et al. (2022b)
	Norway rats	1828	Eradicated (2001)	McClelland (2011)
Antipodes Islands	Sheep	1887	Died out	Taylor (2006)
	Goats	1887	Died out	Taylor (2006)
	Cattle	1889	Died out	Taylor (2006)
	Mice	1908	Eradicated (2016)	Horn et al. (2019)
Auckland Islands <sup>†</sup>	Horses	1849	Removed	Taylor (1968)
	Dogs	1842	Died out	Taylor (1968)
	Possums	1890	Died out	Russell et al. (2020a)
	Sheep	1840	Died out	Taylor (1968)
	Goats	1840	Eradicated (1989–1991)	Brown et al. (2022a)
	Cattle	1850	Eradicated (1991–1993)	Brown and Cox (2022a)
	Rabbits	1840	Eradicated (1993)	Torr (2002)
	Pigs	1807	Extant	Russell et al. (2020a)
	Mice	prior to 1840	Extant	Russell et al. (2020a)
	Cats	prior to 1840	Extant	Russell et al. (2020a)

<sup>†</sup> Russell et al. (2020a, Table 2) and Trotter and Willis (2022) provide details by island for Auckland Island group.

achieving eradication from Auckland Island, with particular issues of scale, lack of ecological knowledge, and technical barriers. The eradication of pigs from Auckland Island was first proposed in 1982 and again in 1993, and first seriously pursued in 2002 (Russell et al. 2018). At that time, knowledge on the home range, habitat use and density of feral pigs on Auckland Island was identified as important for progressing eradication feasibility planning (Anderson et al. 2022). More recently preliminary trials on pig baiting and trapping were undertaken on Auckland Island (Russell et al. 2018; Cox & Macdonald 2022), followed by a localised trial eradication (Cox et al. 2022a), coupled with mainland trials of Judas pig technologies (McInnes et al. 2022).

At the same time as pig eradication was first being actively pursued, cat eradication was also first being proposed, and research on cat diet found they mostly ate land birds, but also relied on mice (Harper 2010a). Knowledge on the home range, habitat use and population density of feral cats on Auckland Island was also identified as important for progressing eradication feasibility planning (Rodríguez-Recio et al. 2022), along with research on feral cat monitoring and detectability (Glen et al. 2022a, b) and bait palatability (Cox et al. 2022b).

Due to the size of Auckland Island, eradication of mice would logistically need to take place over summer for longer days and more favourable weather, but when mice are breeding and alternative food is available. Previous research had revealed complex population cycling (Harper 2010b; Russell et al. 2018) so additional research was undertaken on mouse population dynamics particularly in response to a tussock mast seeding event in 2019 (Sagar et al. 2022). Research revealed that eradication of mice using a lower sowing rate of 4 kg per ha was theoretically feasible (Russell et al. 2019). Such low

sowing rates were subsequently tested for mouse eradication on Adele Island (Livingstone et al. 2022) and Maud Island (Oyston et al. 2022) off the New Zealand mainland, following recent mouse invasions on each island (Pichlmüller et al. 2020).

Removing pigs, cats and mice from such a large island with all the logistical challenges of operating at southern latitudes draws on 3 years of intensive research to clearly establish feasibility to a standard that can satisfy investors (Horn et al. 2022b). The outcome not only has applicability to Auckland Island, but contributes to best-practice eradication on other remote large islands, particularly in the Southern Ocean (de Villiers et al. 2006), such as the Terres Australes et Antarctiques Françaises (Lebouvier & Frenot 2007).

This special issue of the New Zealand Journal of Ecology closely follows ‘Lost Gold’ the recent special edition of the Ornithological Society of New Zealand journal *Notornis* (Miskelly & Symes 2020), which comprehensively sets the scene for the avifaunal values of Auckland Island: what we know; what we have; and what we have lost to the influence of humans and their mammalian hitch-hikers. In this special issue, we pick up the story of those introduced mammals, their history of removal and subsequent island restoration throughout the New Zealand subantarctic region, and the most recent scientific discoveries that provide confidence in removing the last introduced mammals and closing the chapter of degradation in the subantarctic to begin a new era of recovery.

## Author contributions

JCR, SRH and KGB designed the special issue; JCR wrote the editorial, with input from SRH and KGB.

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Rowley Taylor at the coast watchers hut, Ranui Cove, Auckland Island, 10 January 2011 (Photo: Heritage Expeditions)