

The eradication of mammals from New Zealand islands

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Abstract Data on eradication operations against alien mammals on New Zealand islands show that there was a substantial increase in the number of successful eradications in the 1980s and 1990s. The most significant change has been in the ability to eradicate rodents from increasingly large islands (to over 11,000ha), using aerial poisoning techniques. Based on the New Zealand experience, there are good prospects for further eradications of alien mammals from islands around the world, facilitating ecological restoration and the recovery of threatened species. However, instances of reinvasion of rats (*Rattus* spp.) and stoats (*Mustela erminea*) onto previously cleared islands illustrate the importance of prevention, effective monitoring and a fuller understanding of invasion risks.

Keywords: invasive alien species; invasive mammal eradication; eradication on islands; island conservation; New Zealand

INTRODUCTION

Prior to the arrival of humans, the New Zealand terrestrial fauna contained no land mammals, apart from some small bats. The fauna had evolved without mammalian predation and included many endemic species of flightless birds, unusual reptiles, primitive frogs, and large insects. The diverse endemic flora had similarly evolved without mammalian browsing pressure.

The first people to settle in New Zealand, probably less than 800 years ago (Wilmshurst and Higham 2004), were from Polynesia. Associated with this settlement, Pacific rats (*Rattus exulans*) and domestic dogs (*Canis familiaris*) were introduced. Rat predation probably caused the extinction of several small animals, including frogs, small flightless birds, and large flightless insects (Atkinson and Moller 1990; Atkinson and Millener 1991). Overall, at least 40 species of vertebrates (mainly birds) are known to have become extinct, through predation by humans and introduced mammals, in the wake of this first wave of human settlement (Worthy and Holdaway 2002).

The second wave of human colonisation was by Europeans, beginning about 200 years ago. This resulted in the extinction of at least 12 more vertebrates (mostly birds), and the severe decline and range contraction of many other animal and plant species. Among the many alien species introduced to New Zealand by Europeans were a further 52 mammal species, of which 30 became established and 14 are widespread (King 2005).

Several alien mammals have been deliberately introduced to islands around New Zealand (e.g. possums, wallabies, rabbits, pigs, cattle, goats, sheep,



Figure 1 Map of New Zealand, with islands referred to in text.

deer, cats), or have colonised them by accidental transport or natural dispersal (e.g. rodents, stoats) (Russell *et al.* 2004). The spread of some predatory mammals throughout 'mainland' New Zealand has been relatively recent: black rats (*Rattus rattus*) first colonised the North Island in the 1860s and the South Island in the 1890s (Atkinson and Moller 1990), and mustelids were introduced in the late 1880s (King 1990). The subsequent tide of alien predation has exiled many vulnerable native birds and other animals to isolated islands, which have not been colonised by these mammals.

New Zealand has now lost over 40% of its pre-human land-bird fauna (Atkinson and Millener 1991; Worthy and Holdaway 2002) and no other country has a higher proportion of its surviving avifauna classed as threatened (Clout 2001). Of the surviving 287 New Zealand bird species (150 of them endemic), 70 are classed as threatened in the latest IUCN Red List (Baillie *et al.* 2004). Forty-three of these threatened species are endemics, and several of them now exist only on mammal-free islands or in dwindling mainland populations. Islands free of alien mammals are therefore invaluable as wildlife refuges. New Zealand has a large number of islands that are of conservation interest, either because they are still free of invasive mammals, or have the potential for eradication of such animals (Fig. 1). As awareness of the adverse effects of introduced mammals on native wildlife and ecosystems has risen, attempts have increasingly been made to eradicate mammals from such islands, permitting ecological restoration and the recovery or translocation of native biota.

In this paper we collate information on attempts to eradicate alien mammals from New Zealand islands, review these data, analyse trends and success rates, and draw conclusions on the lessons learned. One of our purposes is to bring together all of the information that is currently available, in the hope that its publication will stimulate others to add to the dataset and to update it as further eradications occur in future.

DEFINITIONS AND DATA PRESENTATION

For the purposes of this paper we define an eradication attempt as a project in which the defined goal was complete eradication of an existing population of a particular mammal species from a New Zealand island. Under this definition, we do not include instances of the removal of a single individual of a species, or cases where populations either died out naturally or some time after a 'control' (as opposed to eradication)

campaign of some kind. We collated all available information on attempted eradications from a range of sources, including publications, file reports and personal accounts. Successful eradications are generally deemed to be those where there was no evidence of presence of the target species after the eradication programme was completed. All data on successful eradications are summarised in Tab. 1 of the Appendix. The format is based on the original database of eradications, compiled by Veitch and Bell (1990). The table is organised by species and gives the name of the island concerned, its area, the approximate date when the alien mammal species became established on the island, the eradication team leader, date when the eradication commenced, methods used, date when it was deemed complete, and key references. Data on incomplete, stopped and unsuccessful eradications are provided in Tab. 2 in the Appendix, under similar headings. Data on known re-invasions (i.e. where it is certain that the original population was eradicated and another established subsequently) are given in Tab. 3 of the Appendix.

HISTORY AND TRENDS OF MAMMAL ERADICATIONS

Eradication programmes against mammals on New Zealand islands started in the early 1900s. Rabbits (*Oryctolagus cuniculus*) were eradicated from Ngawhiti Island (5ha) in the Marlborough Sounds in 1912, goats (*Capra hircus*) from South East Island (219ha) in the Chathams group in 1915, and cattle (*Bos taurus*) from Kapiti Island (1965ha) in 1916. Other early eradications include the removal of rabbits from Tiritiri Matangi (196ha) around 1920, cats (*Felis catus*) from Stephens Island (150ha) around 1924, goats from Kapiti Island in 1928, and pigs (*Sus scrofa*) from Aorangi (110ha) in the Poor Knights group in 1936 (Tab. 1 in Appendix). In the 1940s to 1970s eradications were mainly of large or medium-sized mammal species (>10kg), mostly using standard techniques of shooting and trapping. Over this period there were almost no successful planned eradications of small mammals (<1kg), such as rodents (Towns and Broome 2003). This pattern changed dramatically in the 1980s and 1990s, when more eradications occurred and many of them were of rodent populations (Fig. 2).

Prior to the 1980s it was generally thought impossible to eradicate rodents even from small islands. In 1976, Yaldwyn (1978) summed up the conclusions of a conference of experts on the ecology and control of rodents in New Zealand by stating that the prospects

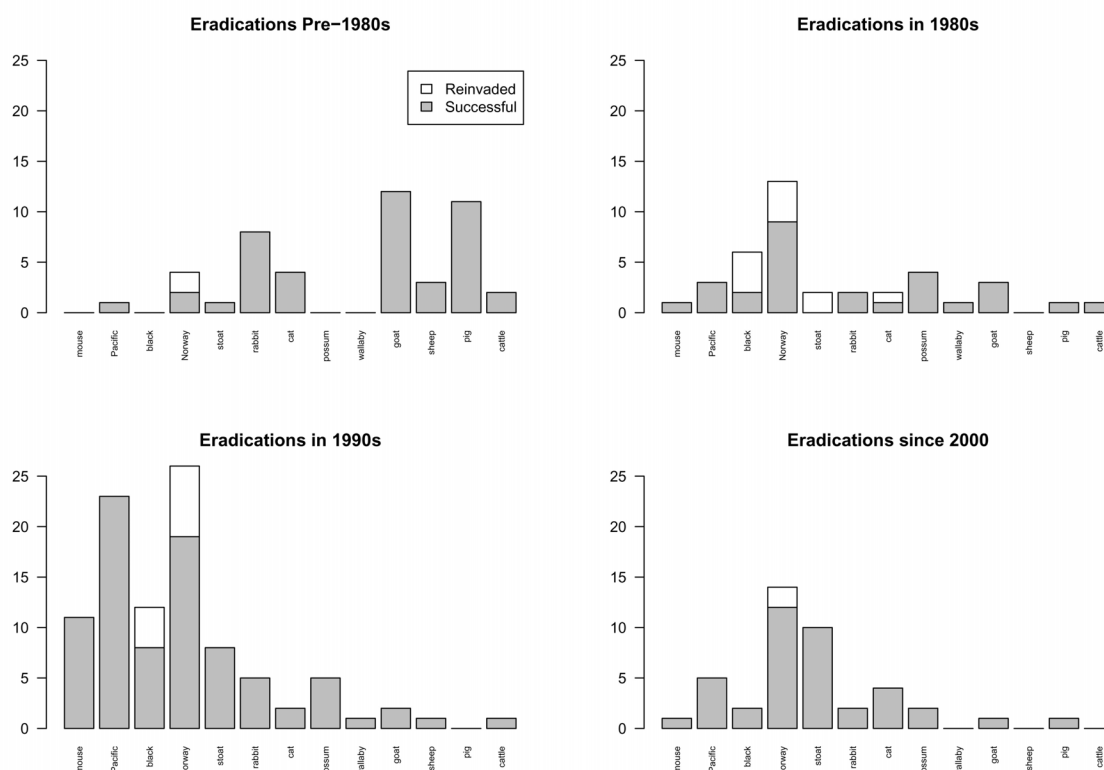


Figure 2 Eradications of alien mammals from New Zealand islands before 1980, during the 1980s, during the 1990s, and since 2000.

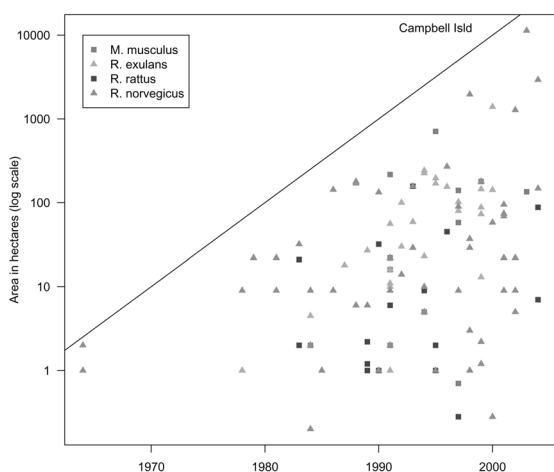


Figure 3 Eradications of alien rodents from New Zealand islands, 1964-2004, showing size of island (ha) and the rodent species eradicated.

for eradication of populations of these mammals from islands were ‘remote’. Key improvements in the potential to eradicate rodents have been the availability from the 1980s of new ‘second generation’

anticoagulant baits, the development of rigorous eradication planning (Cromarty *et al.* 2002), and improved methods of aerial bait distribution. With this enhanced capacity, house mice (*Mus musculus*) have now been eradicated from 13 islands up to 710ha, Pacific rats (*Rattus exulans*) from 32 islands up to 2938ha, black rats (*R. rattus*) from 16 islands up to 157ha (although this includes 4 islands which were subsequently reinvaded by Norway rats), and Norway rats (*R. norvegicus*) from 44 islands up to 11,300ha (Campbell Island, in the New Zealand sub-Antarctic) (Fig. 3).

Some recent rodent eradications have successfully removed two species of rat in the same operation (e.g. on Kapiti, Mayor and Raoul islands). On the other hand, some islands successfully cleared of rats and stoats have subsequently been reinvaded; sometimes more than once (Tab. 3 in Appendix). The number of successful rodent eradication operations (Tab. 1 in Appendix) does not therefore equal the number of islands cleared of these mammals.

Successful eradications of stoats (*Mustela erminea*), especially in Fiordland, have been another feature of the past decade, due to improved trapping technology, careful planning and commitment to preventing reinvasions. Rates of eradication of medium sized

mammals, such as possums, cats and rabbits have also increased since the 1980s, but less dramatically than those for rodents and stoats (Fig 2.). There is still a general trend for larger mammals in particular to have been eradicated from islands of larger maximum area (Fig. 4), but recent eradications of species such as Norway rats from large islands have resulted in this trend being less evident than it was in the past.

SUCCESS AND FAILURE RATES

Unsuccessful or stopped eradication attempts are probably recorded less thoroughly than successes. However, since important lessons can sometimes be learned from failures, some analysis is worthwhile. For example, considering only operations against rodents in the 1990s, there were four stopped eradications and seven unsuccessful ones. Five of the latter were against house mice, including two failures on the same island in

successive years (Tab. 2 in Appendix). Comparing these stopped and unsuccessful eradications with successful ones against rodents in the same decade, eradication success rates in the 1990s were 100% for Pacific rats (n=23) and black rats (n=8), 86% for Norway rats (n=22), and 68% for house mice (n=19). Closer examination of the data for Norway rats reveals that one of the stopped eradications and one of the failed ones in the 1990s were on the same island (Rakino in the Hauraki Gulf), from which this species was successfully eradicated in 2002.

REINVASIONS

The accepted set of conditions for successful eradication (Bomford and O'Brien 1995) are proper planning, a commitment to complete the operation, putting the entire population of the target species at risk, removing them faster than they reproduce, and

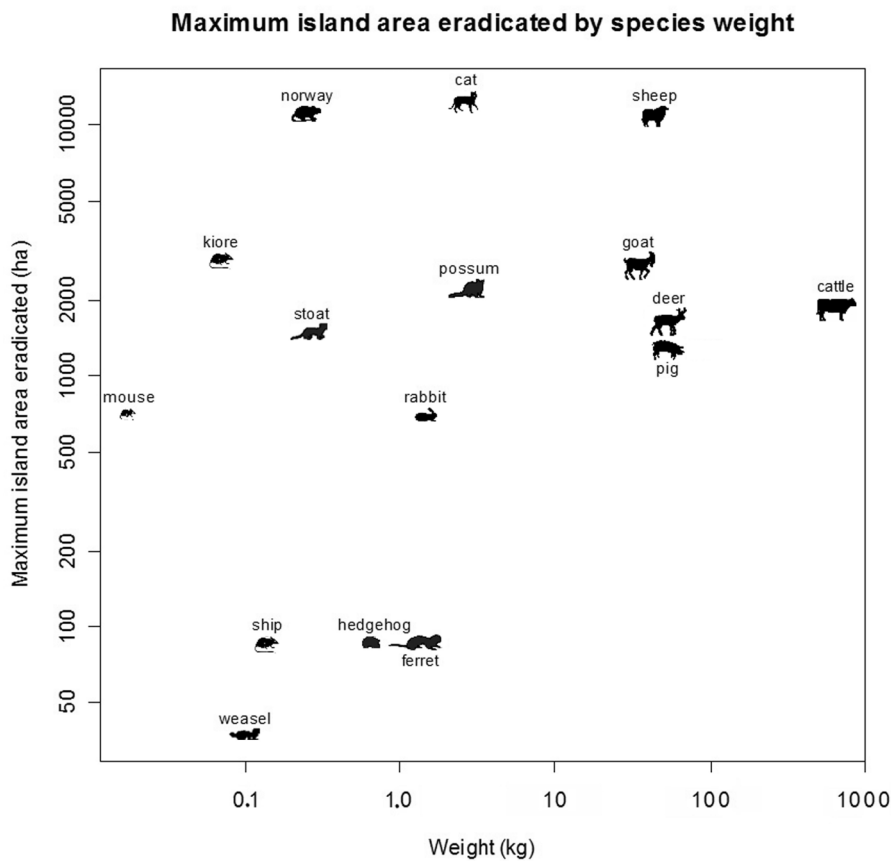


Figure 4 Maximum areas (ha) of New Zealand islands from which particular mammal species have been eradicated, plotted against mean weight (kg) of each species.

preventing reinvasion. For species that can be accidentally reintroduced or can swim across water gaps, reinvasion is a particular concern (Russell et al. 2005). Data on reinvasions of New Zealand islands (Tab. 3 in Appendix) reveals particularly high risks of reinvasion by Norway rats. Since the 1980s there have been four reinvasions of black rats onto islands from which they had previously been eradicated, but at least 19 reinvasions of Norway rats. Six of the latter reinvasions were successive ones on Motuhoropapa (9ha) and four of them on neighbouring Otata (22ha), both in the Noises group, Hauraki Gulf. Reinvasion was most probably occurring from Rakino island, over 2km away, which was completely cleared of all Norway rats in 2002.

Among the other species that have been recorded as reinvading islands (Tab. 3 in Appendix), stoats are a particular conservation concern in New Zealand because of their impacts as predators, combined with the virtual certainty that any female stoat will be pregnant (King 1990) and hence capable of establishing a population. Stoats are capable of swimming at least 1.2km in New Zealand waters (Taylor and Tilley 1984), so any islands less than this distance from a source population (especially in sheltered waters) must be considered to be at risk. The treatment and subsequent careful monitoring of entire local archipelagos, as is being attempted in SW Fiordland (M. Willans pers. comm.) and South Island lakes (S. Thorne pers. comm.), seems the best eradication strategy for these highly mobile and dispersive mammals.

CONCLUSIONS

The rapid rise in the 1980s and 1990s in the number of successful eradications of alien mammals fuelled yet more eradication attempts on larger and larger islands around New Zealand. There was a particularly notable increase in the 1980s in the rate of eradication of rodents and in the increased size of islands from which they were cleared. With careful planning, and the use of modern techniques such as global positioning systems to ensure the even aerial distribution of toxic baits, it is now possible to remove rats from large islands over 10,000ha in area (Towns and Broome 2003). By the end of 2004 there had been 218 successful eradications of 17 different alien mammal species from New Zealand islands. Several of these eradications were of different mammals on the same islands, resulting in many islands that are now free of all alien mammals and therefore have greatly enhanced potential for further ecological restoration.

Along with an improved capacity to eradicate mammals of all species from increasingly large islands, there has been a trend towards targeting two or more species of alien mammals in a single operation. Recent examples of this are the successful joint eradications of Pacific and Norway rats from Kapiti Island; Pacific rats, Norway rats and cats from Mayor and Raoul Islands; and rabbits, black rats and stoats from Quail Island.

Prevention of reinvasion is emerging as another key focus. The reappearance of rat populations on several islands, along with other recent instances of individual rats being seen or caught on supposedly rat-free islands in New Zealand (e.g. Matakohu, Moturoa, and Rotoroa islands), stresses the importance of prevention measures, regular monitoring of supposedly rat-free islands, and a better understanding of the behaviour of invading rodents. There are many islands that have had rodent populations eradicated in the past decade, including several that are close inshore or otherwise vulnerable, so more reinvasions should be anticipated in the future.

New Zealand experience with eradication of alien mammals from islands has obvious relevance for other parts of the world, although the absence of native mammals and the fact that most islands are uninhabited by people makes the situation in New Zealand relatively simple. A major challenge for the future is therefore to improve capacity to conduct multiple eradications of alien species on inhabited islands, and to keep such islands free from reinvasion, so that local people and native biodiversity can both prosper.

ACKNOWLEDGEMENTS

We thank the many people who have provided information on eradications of alien mammals and other animals from New Zealand islands and who have assisted in compilation of the database summarised in the Appendix to this paper. Sources of information, and leaders of eradication operations, are acknowledged in the tables and supporting references in the Appendix. Any omissions or errors are inadvertent. We would be pleased to receive corrections or additional data, so that this information source can be updated in the future.

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The eradication of mammals from New Zealand islands

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APPENDIX

ERADICATIONS OF MAMMALS FROM NEW ZEALAND ISLANDS (TO 2004)

The authors would be grateful to be made aware of any omissions or errors in this compilation.

Table 1. Operations which have resulted in the successful eradication of alien mammals from islands around New Zealand. Methods listed are: P=poison; T=trap; S=shooting; D=dogs. * = date confirmed after a 2 year confirmation process, † = ongoing programme due to high reinvasion risk.

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Date Completed	Reference
HOUSE MOUSE <i>Mus musculus</i>							
Allports (Marlborough)	16	c1900	D. Brown	1989	P	1991*	Brown 1993a
Browns (Hauraki Gulf)	58	?	C. R. Veitch	1995	P	1997*	Veitch 2002a
Enderby (Auckland)	710	1820s	N. Torr	1993	P	1995*	Torr 2002
Mana	217	1800s	P. Todd, T. Hook	1989	P	1991*	Hook & Todd 1992
Mokoia (Lake Rotorua)	135	c1965	B. Mossman	2001	P	2003*	Armstrong et al. 2001
Motuihe (Hauraki Gulf)	179	>1987	C. R. Veitch	1997	P	1999*	Veitch 2002b
Moturemu (Kaipara)	5	?	I. McFadden	1992	P	1994*	I. McFadden pers. comm.
Motutapere (West Coromandel)	45	?	P. Thomson	1994	P	1996*	P. Thomson pers. comm.
Motutapu (Marlborough)	2	?	D. Brown	1989	P	1991*	Brown 1993a
Mou Waho (Lake Wanaka)	140	1995	B. McKinlay	1995	P, T	1997*	McKinlay 1999
Papakohatu (Crusoe)	0.7	?	M. Lee	1996	P, T	1997	Lee 1999
Rimariki	22	?	C. Smuts-Kennedy	1989	P	1991	Veitch & Bell 1990;
Whenuakura (Whangamata)	2	c1980	I. McFadden	1983	P	1984	Newman 1985
PACIFIC RAT <i>Rattus exulans</i>							
Arch (Mokohinau)	1	?	I. McFadden	1990	P	1991	McFadden 1992b
Burgess (Mokohinau)	56	?	I. McFadden	1990	P	1991	McFadden 1994
Codfish (Whenua Hou)	1396	?	P. McClelland	1998	P	2000*	McClelland 2002
Cuvier	170	<1827	P. Thomson	1993	P	1995*	Towns et al. 1995
Double (Mercury)	27	c1900	I. McFadden	1989	P	1989	McFadden 1992a
Fanal (Mokohinau)	73	?	C. R. Veitch	1997	P	1999*	Veitch 2002c
Flax (Mokohinau)	1	?	I. McFadden	1990	P	1991	McFadden 1994

(APPENDIX Table 1 continued)

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Date Completed	Reference
Inner Chetwode (Nukuwaiata)	242	?	D. Brown	1993	P, T, D, S	1994	Brown 1997
Kapiti	1965	<1850	R. Empson	1996	P	1998*	Empson & Miskelly 1999
Korapuki (Mercury)	18	c1900	I. McFadden	1986	P	1987	McFadden & Towns 1991
Lizard (Mokohinau)	1	1977	C. R. Veitch	1978	P	1978	McCallum 1986
Long	142	?	B. Cash	1997	P	2000*	B. Cash pers. comm.
Maori Bay (Mokohinau)	11	?	I. McFadden	1990	P	1991	McFadden 1994
Mauimua (Lady Alice)	155	c1800	K. Hawkins	1994	P	1996*	Towns & Parrish 2003
Mauipae (Coppermine)	80	?	K. Hawkins	1995	P	1997*	Towns & Parrish 2003
Mauiroto (Whatupuke)	102	?	K. Hawkins	1993	P	1997	Towns & Parrish 2003
Mayor (Tuhua)	1277	?	A. Jones	2000	P	2002*	Williams et al. 2000
Middle Chain (Aldermen)	23	?	R. Thorpe	1992	P	1994*	Thorpe 1997
Motuara (Marlborough)	59	?	W. Cash	1991	P	1993*	Cash & Gaze 2000
Motuapao (Far North)	30	?	D. McKenzie	1989	P	1992*	McKenzie 1993
Motupapa 'Stack C' (Mokohinau)	2	?	I. McFadden	1990	P	1991	McFadden 1994
Putauhinu (Stewart)	145	?	P. McClelland	1997	P	1999*	McClelland 2002
Rarotoka (Centre)	88	?	P. McClelland	1997	P	1999*	McClelland 2002
Raoul (Kermadecs)	2938	c1300s	M. Ambrose	2002	P	2004*	M. Ambrose pers. comm.
Red Mercury (Mercury)	225	?	P. Thomson	1992	P	1994*	Towns et al. 1994
Rurima (BOP)	4.5	c1900	I. McFadden	1983	P	1984	McFadden & Towns 1991
Stacks B-G,I,J (Mokohinau)	10	?	I. McFadden	1990	P	1991	McFadden 1994
Stanley (Mercury)	100	<1900	I. McFadden	1991	P	1992	Towns et al. 1993
Tiritiri Matangi (Hauraki Gulf)	196	?	C. R. Veitch	1993	P	1995*	Veitch 2002d
Trig (Mokohinau)	16	?	I. McFadden	1990	P	1991	McFadden 1994
Whakaterepapanui (Rangitoto)	74	?	P. Gaze	1999	P	2001*	P. Gaze pers. comm.
Whangaokena (East)	13	?	D. Peters	1997	P	1999*	Bassett 1999
BLACK RAT <i>Rattus rattus</i>							
Awaiti	2	?	D. Taylor	1982	P	1983	Taylor 1984
Black Rocks (BOI)	1	?	T. Shaw	1992	P	1995*	Shaw 1997
Haulashore (Nelson)	6	?	R. Taylor, B Thomas	1991	P	1991	Thomas & Taylor 2002
Iona (Stewart)	7	?	M. Wylie	2004	P	2004	B. Beaven pers. comm.
Little Rat (BOI)	1	?	D. Taylor	1992	P	1995*	Shaw 1977
Mokopuna (Leper)	1	c1961	S. Butcher	1988	P	1990*	I. McFadden pers. comm.
Mouse (BOI)	1	?	D. Taylor	1992	P	1995*	Shaw 1997
Phil's Hat (BOI)	1	?	D. Taylor	1992	P	1995*	Shaw 1997
Quail (Lyttleton)	88	?	QI Trust, M. Bowie	2002	P	2004*†	Kavermann et al. 2003
Rat (BOI)	2	?	D. Taylor	1992	P	1995*	Shaw 1997
Somes (Wellington)	32	c1961	S. Butcher	1988	P	1990*	McFadden pers. comm.
Tawhitinui	21	?	D. Taylor	1982	P	1983	Taylor 1984
NORWAY RAT <i>Rattus norvegicus</i>							
Black Rocks (BOI)	1	?	T. Shaw	1992	P	1995*	Shaw 1997
Breaksea (Fiordland)	170	1800s	R. Taylor, B Thomas	1988	P	1988	Taylor & Thomas 1993
Browns (Hauraki Gulf)	58	1980s	C. R. Veitch	1995	P	2000	Veitch 2002a
Campbell	11330	c1810	P. McClelland	2001	P	2003*	McClelland & Tyree 2002
David Rocks (Hauraki Gulf)	1	1960	D. Merton	1960	P	1964	Moors 1985a
East & West Atoll (BOI)	1	?	D. Taylor	1992	P	1995*	Shaw 1997
Hauturu (Whangamata)	10	c1972	P. Thomson	1992	P	1994*	Glasse 2004
Hawea (Fiordland)	9	1800s	R. Taylor, B Thomas	1986	P	1986	Taylor & Thomas 1989
Kapiti	1965	<1850	R. Empson	1996	P	1998*	Empson & Miskelly 1999
Koi (Hauraki Gulf)	0.28	2000	M. Lee	2000	P	2000	M. Lee pers. comm.
Maria (Hauraki Gulf)	2	1959	D. Merton	1960	P	1964	Moors 1985a
Matakohe (Limestone)	37	?	J. Crow	1996	P	1998*†	Ritchie 2000
Maukaha Rocks (Whangamata)	0.2	1984	McFadden, Wilke	1984	P	1984	Newman 1985
Mayor (Tuhua)	1277	?	A. Jones	2000	P	2002*	Williams et al. 2000
Mokoia (Lake Rotorua)	133	<1839	P. Jansen	1989	P	1990†	Owen 1997, pers. comm.
Motiti	1	?	A. Walker	1990	P	1990	McKenzie pers. comm.
Motu-O-Kura (Hawkes Bay)	14	c1936	J. Adams	1990	P	1992*	Adams 1997
Motuhoropapa (Hauraki Gulf)	9	2002	G. Wilson	2002	P	2002	Wilson 2003
Motuihe (Hauraki Gulf)	179	1997	C. R. Veitch	1997	P	1999*	Veitch 2002b
Motungara (Kapiti)	3	<1850	R. Empson	1996	P	1998*	Empson & Miskelly 1999
Motutapu (BOI)	1	?	D. McKenzie	1990	P	1990	D. McKenzie pers. comm.
Motuterakihī	1	?	D. Taylor	1985	P	1985	D. Taylor pers. comm.
Moutohora (Whale)	143	c1920	P. Jansen	1985	P	1986	Jansen 1993
Otata (Hauraki Gulf)	22	2002	G. Wilson	2002	P	2002	Wilson 2003
Pakatoa (Hauraki Gulf)	29	1997	M. Lee	1998	P	1998*†	M. Lee pers. comm.
Puangiangi (Rangitoto)	69	?	P. Gaze	1999	P	2001*	D. Brown pers. comm.

The eradication of mammals from New Zealand islands

(APPENDIX Table 1 continued)

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Date Completed	Reference
Rakino (Hauraki Gulf)	148	1920-72	Hix, Waters, Wilson	2002	P	2004*†	MacKenzie pers.comm.
Raoul (Kermadecs)	2938	1921	M. Ambrose	2002	P	2004*	M. Ambrose pers. comm.
SW Crater Rim (BOI)	1	?	D. Taylor	1992	P	1995*	Shaw 1997
Tahoramaurea (Kapiti)	1	<1850	R. Empson	1996	P	1998*	Empson & Miskelly 1999
Takangaroa	6	1987	T. Clarkson	1988	P	1988	Taylor 1989
Tarahiki	5	c1998	G. Wilson	2000	P	2002*	G. Wilson pers. comm.
Taranaki (BOI)	1	?	D. McKenzie	1990	P	1990	D. McKenzie pers. comm.
Te Haupa (Saddle)	6	<1981	R. Gilfillan	1989	P	1989	Tennyson & Taylor 1999
Tinui (Rangitoto)	95	?	P. Gaze	1999	P	2001*	D. Brown pers. comm.
Titi (Marlborough)	32	<1955	B. Bell, D. Merton	1970	P	1983*	Gaze 1983
Unnamed Cape Wiwiki A ('Snail Rock')	2.2	1989-99	A. Walker	1999	P	1999	R. Parrish pers. comm.
Unnamed Cape Wiwiki B ('Gorse Island')	1.2	1989-99	A. Walker	1999	P	1999	R. Parrish pers. comm.
Ulva (Stewart)	270	?	L. Chadderton	1992	P	1996†	Thomas & Taylor 2002
Wainui (BOI)	2	?	D. McKenzie	1991	P	1991	D. McKenzie pers. comm.
Whakaterepapanui (Rangitoto)	74	?	P. Gaze	1999	P	2001*	D. Brown pers. comm.
Whenuakura (Whangamata)	2	c1982	McFadden, Wilke	1983	P	1984	Newman 1985
WEASEL <i>Mustela nivalis vulgaris</i>							
Matakohe (Limestone)	37	?	J. Craw	1996	T	1996†	Ritchie 2000
STOAT <i>Mustela erminea</i>							
Adele (Nelson)	88	1982	T. Shaw	2003	T	2004†	T. Shaw pers. comm.
Anchor (Fiordland)	1280	?	Willans, Munn, Elliott	2001	T	2001†	Willans 2002
Bauza (Fiordland)	475	?	Willans, Elliott	2002	T	2003†	Willans 2002
Te Kakahu (Chalky)	511	?	Willans, Munn	1999	T	1999	Willans 2000
Doubtful east (Lake Te Anau)	120	?	M. Willans	2000	T	2002†	Willans 2002
Doubtful centre (Lake Te Anau)	40	?	M. Willans	2000	T	2002†	Willans 2002
Doubtful west (Lake Te Anau)	120	?	M. Willans	2000	T	2002†	Willans 2002
Erin (Lake Te Anau)	75	?	M. Willans	2000	T	2002†	Willans 2002
Matakohe (Limestone)	37	?	J. Craw	1996	T	1996†	Ritchie 2000
Maud (Marlborough)	309	c1989	D. Crouchley	1990	T, S	1993†	Crouchley 1993
Moturoa (BOI)	157	?	P. Asquith	1993	T	1993†	Asquith 2004
Mou Waho (Lake Wanaka)	140	?	S Thorne, J Flemmin	1997	T	1997†	S. Thorne pers. comm.
Mou Tapu (Lake Wanaka)	120	?	S Thorne, J Flemmin	1997	T	1997†	S. Thorne pers. comm.
North Passage (Fiordland)	10	?	M. Willans	1998	T, D	2000	Willans 2000
Otata (Hauraki Gulf)	22	1948	Captain Wainhouse	?	S	1955	B. Neureuter pers. comm.
Quail (Lyttleton)	88	?	Quail Isld Trust	2002	T	2004*†	Kavermann et al. 2003
Silver (Lake Hawea)	25	?	S Thorne, J Flemmin	1997	T	1997†	S. Thorne pers. comm.
South Passage (Fiordland)	176	?	M. Willans	1998	T, D	2000	Willans 2000
Stevensons (Lake Wanaka)	65	?	S Thorne, J Flemmin	1997	T	1997†	S. Thorne pers. comm.
FERRET <i>Mustela furo</i>							
Quail (Lyttleton)	88	?	Quail Isld Trust	2002	T	2002†	Kavermann et al. 2003
HEDGEHOG <i>Erinaceus europaeus</i>							
Quail (Lyttleton)	88	?	QI Trust, M. Bowie	1999	P, T	2003	Thomsen et al. 2000
RABBIT <i>Oryctolagus cuniculus</i>							
Browns (Hauraki Gulf)	58	c1975	F. David	1985	P, T, D, S	1991	Veitch 2002a
Enderby (Auckland)	710	1865	N. Torr	1993	P, T, D, S	1994	Torr 2002
Korapuki (Mercury)	18	c1900	I. McFadden	1986	P, S	1988	Towns 2002
Mokopuna (Leper)	1	c1946	L. Bell	1947	?	1950	Anon 1951
Motuihe (Hauraki Gulf)	179	?	S. Mowbray	2002	P, S	2004	D. Thompson pers. comm
Motunau (Canterbury)	3	c1850	Motunau Rabbit Bred	1958	P, S	1962	Cox et al. 1967
Moutohora (Whale)	143	1968	P. Jansen	1985	P, T	1987	Jansen 1993
Native (Stewart)	66	c1942	S. Corboy	c1949	T, S	1950	R. Taylor pers. comm.
Ngawhiti (Marlborough)	5	c1910	?	c1912	?	c1912	Gibb & Williams 1990
Otata (Hauraki Gulf)	15	?	Captain Wainhouse	?	S	1945	B. Neureuter pers. comm.
Quail (Lyttleton)	88	c1855	J. Trotter	1997	P, T, D, S	2004	D. Brown pers. comm.
Rose (Auckland)	75	1850	N. Torr	1993	P, T, D, S	1994	Torr 2002
Stanley (Mercury)	100	c1900	I. McFadden	1991	P	1992	Towns et al. 1993
Stewart [part]	?	1942	Dept Agriculture	c1948	T, S	1950	R. Taylor pers. comm.
Taieri (Dunedin)	7	?	J. Pearce	1987	P	1996	J. Pearce pers. comm.
Takangaroa	6	<1930	T. Clarkson	?	S	<1950	Taylor 1989
Tiritiri Matangi (Hauraki Gulf)	196	<1894	E. Hobbs	c1900	?	c1920	Veitch 2002d

(APPENDIX Table 1 continued)

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Date Completed	Reference
CAT <i>Felis catus</i>							
Cuvier	170	c1889	D. Merton	1960	T, S	1964	Merton 1970
Herekopare (Stewart)	28	c1925	C. R. Veitch	1970	T, D	1970	Fitzgerald & Veitch 1985
Kapiti	1965	c1900	R. Fletcher	1923	S	1934	Fuller 2004
Hauturu (Little Barrier)	3083	<1870	C. R. Veitch	1977	P, T, D	1980	Veitch 2001
Macquarie	13182	1820	Tasmanian Parks & Wildlife	1997	P, T, D, S	2003	Copson & Whinam 2001
Matakohe (Limestone)	37	?	Clapperton, Pierce	1991	P	1991	Clapperton et al. 1992
Mayor (Tuhua)	1277	?	A. Jones	2000	P	2002	Williams et al. 2000
Motuihe (Hauraki Gulf)	160	c1984	S. Mowbray	2002	T, S	2004	D. Thompson pers. comm.
Quail (Lyttleton)	88	<1983	D. Brown	1998	T, S	1998	D. Brown pers. comm.
Raoul (Kermadecs)	2938	1836-72	M. Ambrose	2002	P, T, D	2004	M. Ambrose pers. comm.
Stephens	150	<1895	Lighthouse keepers	1895	S	c1924	Brown 2000
BRUSHTAIL POSSUM <i>Trichosurus vulpecula</i>							
Allports (Marlborough)	16	<1980	D. Brown	1989	P, T	1990	Brown 1993b
Codfish (Whenua Hou)	1396	<1925	A. Cox, G. Aburn	1984	P, T, D	1987	Brown unpubl. Brown 2002
Iona (Stewart)	7	c1984	M. Wylie	2004	T	2004	B. Beaven pers. comm.
Kapiti	1965	1893	Alexander, Cairns	1980	P, T, D, S	1986	Cowan 1992
Matakohe (Limestone)	37	?	C. Cooper	1991	S	1991	Clapperton et al. 1992
Motutapere (West Coromandel)	45	<1970	P. Thomson	1994	P	1996	P. Thomson pers. comm.
Motutapu (Hauraki Gulf)	1560	1868	S. Mowbray	1990	P, T, D	1996	Mowbray 2002
Rangitoto (Hauraki Gulf)	2321	1868	S. Mowbray	1990	P, T, D	1997	Mowbray 2002
Unnamed Cape Wīwī A ('Snail Rock')	2.2	?	D. Taylor, T. Shaw	1989	P	1989	Parrish et al. 1995
Unnamed Cape Wīwī B ('Gorse Island')	1.2	?	D. Taylor, T. Shaw	1989	P	1989	Parrish et al. 1995
BRUSH-TAILED ROCK WALLABY <i>Petrogale penicillata</i>							
Motutapu (Hauraki Gulf)	1560	1868	S. Mowbray	1990	P, T, D	1996	Mowbray 2002
Rangitoto (Hauraki Gulf)	2321	1868	S. Mowbray	1990	P, T, D	2000	Mowbray 2002
Great Barrier [part-Reef Point]	?	1980	A. Leigh, K. Purdon	1981	T	1981	Eadie et al. 1990
GOAT <i>Capra hircus</i>							
Auckland [part]	4000	1865	K. Timpson, Willense, Cox	1989	P, S	1991	Brown unpubl.
Burgess (Mokohinau)	56	?	C. R. Veitch	1973	S	1973	Veitch 1973
Cuvier	170	1890s	B. Bell	1959	S	1961	Merton 1970
Ernest (Stewart)	25	<1909	Muttonbirders	1980s	?	1980s	Parkes 1990
Great (Three Kings)	407	1889	L. Bell	1946	S	1946	Turbott 1948
Herekopare (Stewart)	28	1973	Muttonbirders	1975	S	1976	R. Tindall pers. comm.
Nukuwaiata	242	?	C. Smuts-Kennedy	1993	S	1993	C. Smuts-Kennedy pers. comm.
Kapiti	1965	c1830	A. S. Wilkinson	1924	S	1928	Wilkinson 1952
Macauley (Kermadecs)	236	<1836	B. Bell	1966	S	1966	Williams & Rudge 1969
Mahurangi	23	c1900	?	?	?	1915	Atkinson 1972
Moturekareka	19	?	C. Hansen	?	S	?	Tennyson et al. 1997
Moutohora (Whale)	143	c1890	NZ Wildlife Service	1971	S	1977	Ogle 1990
Nukutaunga (Cavalli)	13	?	C. Smuts-Kennedy	1972	S	1972	Miller 1976
Ocean (Auckland)	3	1865	CAPE Expedition	1941	S	1943	Rudge & Campbell 1977; Brown unpubl.
Rakitu (Arid)	328	?	D. Agnew	2002	S	2002	Agnew 2002
Raoul (Kermadecs)	2938	<1836	NZ Forest Service	1972	D, S	1984	Parkes 1990
South East (Chathams)	219	1900	Mr McLurg	1914	?	1915	Ritchie 1970
Pouawa	6	?	Andy Bassett	1987	S	1987	A. Bassett pers. comm.
Whangaokena (East)	13	1906	G. Goldsmith	1960	S	1960	H. Hovell pers. comm.
SHEEP <i>Ovis aries</i>							
Campbell	11330	1895	Bell, Torr, Cox	1970	S	1991	Brown unpubl.
Kapiti	1965	1850s	P. Rodda	1928	S	1930	Fuller 2004
Mangere (Chathams)	113	c1900	B. Bell	1968	S	1968	B. Bell pers. comm..
South East (Chathams)	219	1914	B. Bell	1957	S	1961	Ritchie 1970
RED DEER <i>Cervus elaphus scoticus</i>							
Anchor (Fiordland)	1525	?	Willans, Munn	2002	D, S	2004†	M. Willans pers. comm.
PIG <i>Sus scrofa</i>							
Aorangi (Poor Knights)	110	c1820	Major Yerex	1936	S	1936	Challies 1976

The eradication of mammals from New Zealand islands

(APPENDIX Table 1 continued)

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Date Completed	Reference
Blumine (Oruawairua)	377	c1840	M. Finch	1989	D, S	1989	Clarke et al. 1991
Inner Chetwode (Nukuwaiata)	242	c1900	?	?	S	1926	Internal Affairs Files
Inner Chetwode (Nukuwaiata)	242	c1954	D. Cummings	1959	D, S	1963	Internal Affairs Files
Mayor (Tuhua)	1277	?	A. Jones	2000	D, S	2002	A. Jones pers. comm.
Motuara (Marlborough)	59	c1840	?	1920s	P, D, S	1950s	Clarke et al. 1991
Motuoruhi (West Coromandel)	57	?	?	?	?	<1970	McIlroy 1990
Outer Chetwode (Te Kakaho)	81	c1948	?	1953	S	1953	Internal Affairs Files
Outer Chetwode (Te Kakaho)	81	c1955	D. Cummings	1964	S	1964	Internal Affairs Files
Pickersgill	103	c1840	?	1920s	P, D, S	1950s	Clarke et al. 1991
Rakitu (Arid)	328	?	?	?	?	1960s	McIlroy 1990
Stewart [part]	1040	?	Purdon, Vipond	1948	D, S	1948	Holden 1982
Tuputupungahau (Whale)	13	1950s	Owners	?	?	c1966	Wright 1977
CATTLE <i>Bos taurus</i>							
Campbell [part]	2000	1902	Ron Peacock	1984	S	1984	Brown unpubl.
Enderby (Auckland)	710	1894	Nick Torr	1991	S	1993	Torr 2002; Brown unpubl.
Kapiti	1965	c1837	J. L. Bennett	1916	S	1916	Wilkinson 1952
Stewart [part]	?	?	D. Internal Affairs	1940s	S	1940s	Taylor 1976

Table 2 Operations which have not resulted in the eradication of an alien mammal species from an island. These operations are listed as: “incomplete” where the work is continuing or confirmation of the eradication has not been obtained; “stopped” where the work was stopped due to a management decision before the planned work was completed; “failed” where the planned programme was completed and eradication was not successful. Methods listed are: P=poison; T=trap; S=shooting; D=dogs.

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Reference
<u>INCOMPLETE</u>						
HOUSE MOUSE <i>Mus musculus</i>						
Mou Tapu (Lake Wanaka)	120	?	S Thorne, J Flemmin	1997	P	S. Thorne pers. comm.
Quail (Lyttleton)	88	?	QI Trust, M. Bowie	2002	P	M. Bowie pers. comm.
PACIFIC RAT <i>Rattus exulans</i>						
Bench (Stewart)	121	?	M. Wylie	2005	P	B. Beaven pers. comm.
Hauturu (Little Barrier)	3083	?	R. Griffiths	2004	P	R. Griffiths pers. comm.
Macaulay (Kermadecs)	236	c1300s	M. Ambrose	2005	P	M. Ambrose pers. comm.
Mokinui (Big Moggy)	86	?	P. McClelland	2005	P	D. Agnew pers. comm.
Ohinau (East Coromandel)	143	?	J. Roxburgh	2005	P	J. Roxburgh pers. comm.
Pearl (Stewart)	512	?	M. Wylie	2005	P	B. Beaven pers. comm.
BLACK RAT <i>Rattus rattus</i>						
Fortyseven (BOI)	1	?	D. Taylor	1990	P	D. Taylor pers. comm.
Harakeke (BOI)	12	?	D. Taylor	1992	P	D. Taylor pers. comm.
Horomamae (Owen)	36	?	J. Ryan	2004	P	D. Agnew pers. comm.
Motukaha (Hauraki Gulf)	0.4	?	I. McFadden, M. Lee	1996	P	Lee 1999
Moturako (GBI)	1	?	G. Taylor	1990	P	G. Taylor pers. comm.
Motutapere (West Coromandel)	45	2002	R. Chappell	2005	P	R. Chappell pers. comm.
Opakau (GBI)	4	?	G. Taylor	1990	P	G. Taylor pers. comm.
Oyster (GBI)	1	?	G. Taylor	1990	P	G. Taylor pers. comm.
Pearl (Stewart)	512	?	M. Wylie	2005	P	B. Beaven pers. comm.
Pukeweka (Stewart)	3	1960s	P. McClelland	2005	P	D. Agnew pers. comm.
Saddle (GBI)	2	?	G. Taylor	1990	P	G. Taylor pers. comm.
Taukihepa (Big South Cape)	939	1960s	P. McClelland	2005	P	D. Agnew pers. comm.
Whakarereupoko (Rerewhakaupoko)	26	1960s	P. McClelland	2005	P	D. Agnew pers. comm.
Wood (GBI)	1	?	G. Taylor	1990	P	G. Taylor pers. comm.
Wood Stack A (GBI)	1	?	G. Taylor	1990	P	G. Taylor pers. comm.
NORWAY RAT <i>Rattus norvegicus</i>						
Moturemu (Kaipara)	5	2002	T. Wilson	2004	P	Russell et al. unpubl.

(APPENDIX Table 2 continued)

Location	Area	Date Introduced	Eradication Leader	Date Started	Methods	Reference
Moturoa (BOI)		157 1997	P. Asquith	2003	P	Asquith 2004
Pearl (Stewart)		512 ?	M. Wylie	2005	P	B. Beaven pers. comm.
RABBIT <i>Oryctolagus cuniculus</i>						
Ohinau (East Coromandel)		143 ?	J. Roxburgh	2005	P	J. Roxburgh pers. comm.
BRUSHTAIL POSSUM <i>Trichosurus vulpecula</i>						
Fortyseven (BOI)		1 ?	D. Taylor	1990	P	D. Taylor pers. comm.
Harakeke (BOI)		12 c1990	D. Taylor	1992	P	D. Taylor pers. comm.
Peach (Whangaroa)		11 ?	D. Taylor	1990	P, T	D. Taylor pers. comm.
Pig (Lake Whakatipu)		110 c1975	R Hoetjes, B Barron	1990	P, T	B. Barron pers. comm.
Pigeon (Lake Whakatipu)		168 c1975	R Hoetjes, B Barron	1990	P, T	B. Barron pers. comm.
Tarakaipa		35 ?	P. Brady	1991	P, T, D	B. Brown pers. comm.
GOAT <i>Capra hircus</i>						
Great Barrier [part]		4030 ?	K. Broome	1986	S, D	Parks 1990
Great Barrier		27761 ?	?	?	S	D. Agnew pers. comm.
Pourewa (East Coast)		42 <1950	M. Hockey	1992	S	? Whiting pers. comm.
STOPPED						
HOUSE MOUSE <i>Mus musculus</i>						
Silver (Lake Hawea)		25 ?	S Thorne, J Flemmin	1997	P	S. Thorne pers. comm.
Stevensons (Lake Wanaka)		65 ?	S Thorne, J Flemmin	1997	P	S. Thorne pers. comm.
PACIFIC RAT <i>Rattus exulans</i>						
Mauipae (Coppermine)		80 ?	D. McKenzie	1992	P	Tyrrell et al. 2000; R. Parrish pers. comm.
NORWAY RAT <i>Rattus norvegicus</i>						
Rakino (Hauraki Gulf)		148 1920-72	M. Lee	1997	P	M. Lee pers. comm.
RABBIT <i>Oryctolagus cuniculus</i>						
Motuihe (Hauraki Gulf)		179 ?	C. R. Veitch	1997	P, T, D	Veitch 2000b
Quail (Lyttleton)		88 c1855	J. Trotter	1988	P	J. Trotter pers. comm.
CAT <i>Felis catus</i>						
Motuihe (Hauraki Gulf)		179 ?	C. R. Veitch	1997	P	Veitch 2000b
Raoul (Kermadecs)		2938 c1850	C. R. Veitch	1972	T	Fitzgerald et al. 1991
RED DEER <i>Cervus elaphus scoticus</i>						
Secretary (Fiordland)		8140 <1965	J. von Tunzelman	1974	P, S	Mark & Baylis 1982
UNSUCCESSFUL						
HOUSE MOUSE <i>Mus musculus</i>						
Hauturu (Whangamata)		10 c1980	P. Thomson	1994	P	Glassey 2004
Matakohe (Limestone)		37 ?	J. Craw	1997	P	Ritchie 2000
Matakohe (Limestone)		37 ?	J. Craw	1998	P	Ritchie 2000
Matakohe (Limestone)		37 ?	D. Kokich	2001	P	Brackenbury 2001
Mokoia (Lake Rotorua)		135 c1965	M. Wilke	1996	P	Owen 1997, 1998
Te Haupa (Saddle)		6 ?	B. Green	1993	P	T. Wilson pers. comm.
NORWAY RAT <i>Rattus norvegicus</i>						
Rakino (Hauraki Gulf)		148 1920-72	McCrae, Ellis, Lee	1992	P	M. Lee pers. comm.
Rotoroa (Hauraki Gulf)		90 ?	N. Stark	1991	P	M. Lee pers. comm.
RABBIT <i>Oryctolagus cuniculus</i>						
Quail (Lyttleton)		88 c1855	Banks Peninsula Pest Destruction Board	1982	P, S	D. Brown pers. comm.
BRUSHTAIL POSSUM <i>Trichosurus vulpecula</i>						
Allports (Marlborough)		16 <1980	T. Neal	1982	P, T	D. Brown pers. comm.

The eradication of mammals from New Zealand islands

Table 3 Operations which resulted in the successful eradication of an alien mammal species from an island, but where the species re-invaded at a later date. Methods listed are: P=poison; T=trap; S=shooting; D=dogs. † = ongoing programme due to high reinvasion risk. § Reinvasion by Norway rats (*Rattus norvegicus*).

Location	Area	Date Introduced	Eradication Leader	Date Completed	Methods	Date re-invaded	Reference
RE-INVASION							
BLACK RAT <i>Rattus rattus</i>							
Duffers Reef (Marlborough)	2	<1983	D. Taylor	1983	P, T	c1990	D. Brown pers. comm.
Goat (Leigh)	9	<1977	T. Wilson	1994	P	1996	T. Wilson pers. comm.
Kauwahaia	1	?	G. Taylor	1989	P	1990s	Taylor & Cameron 1990
Koi (Hauraki Gulf)	0.28	?	M. Lee	1997	P, T	2000§	Lee 1999
Moturoa (BOI)	157	c1800	P. Asquith	1993	P	1997§†	Asquith 2004
Motutapere (West Coromandel)	45	?	P. Thomson	1996	P	2002	R. Chappell pers. comm.
Unnamed Cape Wiwiki A ('Snail Rock')	2.2	?	D Taylor, T. Shaw	1989	P	<1999§	Parrish et al. 1995
Unnamed Cape Wiwiki B ('Gorse Island')	1.2	?	D Taylor, T. Shaw	1989	P	<1999§	Parrish et al. 1995
NORWAY RAT <i>Rattus norvegicus</i>							
Motuhoropapa (Hauraki Gulf)	9	2001	G. Wilson	2001	P	2002	Wilson 2003
Motuhoropapa (Hauraki Gulf)	9	1996	I. McFadden	1997	P	2001	Cameron 1998
Motuhoropapa (Hauraki Gulf)	9	1987	I. McFadden	1991	P	1996	Cameron 1998
Motuhoropapa (Hauraki Gulf)	9	1983	P. Moors	1984	P	1987	Moors 1985b
Motuhoropapa (Hauraki Gulf)	9	1981	P. Moors	1981	P	1983	Moors 1985b, 1987
Motuhoropapa (Hauraki Gulf)	9	<1962	P. Moors	1978	T	1981	Moors 1981, 1985b
Motuihe (Hauraki Gulf)	179	<1987	?	1988	P	1997	Veitch 2002b
Moturemu (Kaipara)	5	?	I. McFadden	1994	P	2002	J. Russell pers. comm.
Moturoa (BOI)	157	c1800	P. Asquith	1993	P	1997§†	Asquith 2004
Otata (Hauraki Gulf)	22	<2001	G. Wilson	2001	P	2002	Wilson 2003
Otata (Hauraki Gulf)	22	1991	I. McFadden	1991	P	2001	Cameron 1998
Otata (Hauraki Gulf)	22	1980	P. Moors	1981	P	1991	Moors 1985b, 1987
Otata (Hauraki Gulf)	22	1956-57	P. Moors	1979	P, T	1980	Moors 1981, 1985b
Pakatoa (Hauraki Gulf)	29	?	M. Lee	1993	P	1997	M. Lee pers. comm.
Rotoroa (Hauraki Gulf)	90	?	M. Lee	1997	P	c1999†	M. Lee pers. comm.
STOAT <i>Mustela erminea</i>							
Adele (Nelson)	88	<1977	R. Taylor	1981	T	1982	Taylor & Tilley 1984
Maud (Marlborough)	309	c1980	W. Cash	1983	T	1989	Crouchley 1992
CAT <i>Felis catus</i>							
Motuihe (Hauraki Gulf)	160	c1800	Steve Boyle	1981	S	c1984	Veitch 1985, 2002b

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The eradication of mammals from New Zealand islands

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