

14 Terrestrial mammals and mammalian pests

Introduction

Apart from marine mammals and bats, the only mammals present in New Zealand were introduced, intentionally or not, from other parts of the world. Because they had either no, or very few, natural predators here, many of them increased enormously and became environmental and economic pests. Consequently, this chapter deals mainly with these pests, which fall into three categories:

Rodents: Three species of rat, and mice, are the smallest of the mammalian pests. While primarily herbivorous, they also eat insects, birds, lizards and other things, and are thus classified as omnivorous. These small animals have short life-cycles and are capable of very rapid reproduction, so that populations can reach plague proportions. Rabbits are related to the rodents, but are more strictly herbivorous and less adaptable in terms of both food and habitat.

Carnivores: In this category are feral cats, feral dogs and mustelids (weasel, stoat and ferret). Mustelids are not present on Great Barrier Island. Feral cats and dogs are medium sized animals capable of preying on rodents and rabbits, but also liable to eat native biota, especially birds and lizards.

Large Herbivores (Ungulates): On Great Barrier Island these include feral goats (now exterminated), feral cattle and pigs. Fallow deer have recently been eliminated from Motu Kaikoura and are not present elsewhere. These large animals damage bush regeneration, and when numerous can create soil erosion.

These three groups of ‘unwanted’ organisms form a hierarchy from those most difficult to control or eliminate (rodents), to those which are easier. However, large herbivores are only *relatively* easy to eliminate because they are fewer in absolute number, and have relatively slow rates of reproduction. In fact the removal of even these animals from large areas of rugged country is a major undertaking.

In this chapter we discuss each of these as they relate to Great Barrier Island. We outline their current status on the Island and make some comments about environmental benefits that could result from their control or elimination in the future. In this context we present data on the other Islands in the Hauraki Gulf, many of which have had their former pests eradicated. Much knowledge has been gained from these (and other) ‘island eradications’, some of which is applicable to the more difficult question of pest eradication on Great Barrier Island.

Bats

The only land mammals known from New Zealand are three species of bat. One of these, the greater short-tailed bat (*Mystacina robusta*), has become extinct since European arrival. The other two are respectively the lesser short-tailed bat (*Mystacina tuberculata*) and the long-tailed bat (*Chalinolobus tuberculatus*). The former is an endangered endemic with no close extant relatives anywhere on earth, and the peculiar habit of foraging on the ground for insects. It is known also to pollinate the rare parasitic plant *Dactyloctenium aegyptium*, formerly

present on Great Barrier Island. The long-tailed bat is the sole New Zealand representative of a genus which also occurs in Australia, New Guinea and New Caledonia. Unlike the short-tailed bat it is an aerial insectivore. It too, is endangered.

Long tail bats were confirmed on Great Barrier Island in 1980. Short tailed bats have not yet been found although they are present on Hauturu. A survey using automatic bat boxes along the Tataweka track in 2008 failed to detect short-tailed bats, although this doesn't mean they're not there!ⁱ A walking survey using hand held bat detectors in 2004/2005 detected this species at Fitzroy, Kaiaraara, Okiwi, Kaitoke/Claris, and Awana. They are often seen at Miner's Cove and there have also been unconfirmed reports of bats from Medlands and Tryphena although none were detected during the walking surveys.ⁱⁱ

Overview of introduced mammals

At least 50 species of mammals have been introduced to New Zealand since the late eighteenth century. The impacts of browsing and grazing mammals on the indigenous vegetation is widely regarded as an ecological disaster, involving extensive loss of cover and resulting in accelerated erosion in the high countryⁱⁱⁱ. Great Barrier Island has been fortunate in having avoided the worst of these effects, because red deer (*Cervus elaphus*) and possums (*Trichosorus vulpecula*) have never been present on the Island. Although wallaby (*Pterogale pencillata*) and goat (*Capra hircus*) were formerly present, these have now been eradicated. Fallow deer (*Dama dama*), present only on Motu Kaikoura, have also recently been eliminated (2009). The Island has no mustelids (weasles, stoats, ferrets), Norway rats or hedgehogs (*Erinaceus europaeus*), and this has been important for the survival of species which have declined on the mainland.

However, ship rat, kiore and mice are present on Great Barrier Island in abundance (Fig 14.1), and with feral cats, pose a well-documented risk to the continued existence of many rare species of birds and lizards. Pet domestic dogs and cats also pose a risk. There are recent instances of domestic dogs killing shags and one uncontrolled dog could have a devastating effect at a pateke flock site. Domestic cats are known to have killed six chevron skinks, and this is likely to represent only a tiny proportion of the actual slaughter. However, domestic pets should be a manageable risk.

Browsing mammals currently present are wild cattle and pigs. Pigs are likely to have impacts on rare plants such as *Dactylanthus taylori*, bats, native frogs, lizards and ground-nesting birds. Both cattle and pigs are having severe impacts on forest regeneration in some areas.

Fig 14.1 Summary of mammalian pest status on Great Barrier Island

Island	Eradicated	Present	Absent
Great Barrier Island (Aotea)	feral goat, wallaby	cat, mouse, pig, rabbit, wild cattle, Australian growling grass frog, ship rat & kiore  ship rat (top) & kiore (below). Estimated GBI rodent population: 286,000 !	Norway rat, possum, mustelids (stoat, weasel, ferret), hedgehog, red deer  Norway rat
Kaikoura Island ^{iv}		fallow deer*, pig*, kiore, ship rat*, mouse	 Possum Estimated GBI population: 0!
Rakitu (Arid Island) ^v	feral goat, pig	kiore, ship rat	 Ferret – the largest of the Mustelids. Fortunately never released on Great Barrier Island!
Other small islands off Aotea ^{vi}		cat, kiore, mouse, rabbit, ship rat**	

* = eradication underway ** = eradication also planned for privately owned Nelson, Motuhaku, Sugar Loaf group, Grey group, Opakau, and Moturako. Photos: DOC Website and J. Ogden.

Photo: DoC Website

Success story – the eradication of goats

Feral goats (*Capra hircus*) are well known to have a very broad diet, and are capable of eliminating forest regeneration. Their devastating effects on the northern bush (Te Paparahi) are well documented.^{vii} Goats were finally eliminated after a combined Department of Conservation / Auckland Regional Council offensive in 2005. This was a good example of major agencies working together with contractors, local land-owners and other members of the community for a common goal^{viii}. It demonstrates what is possible. Unfortunately some islanders still keep goats, so that, although there are strict regulations, the possibility of re-invasion remains.

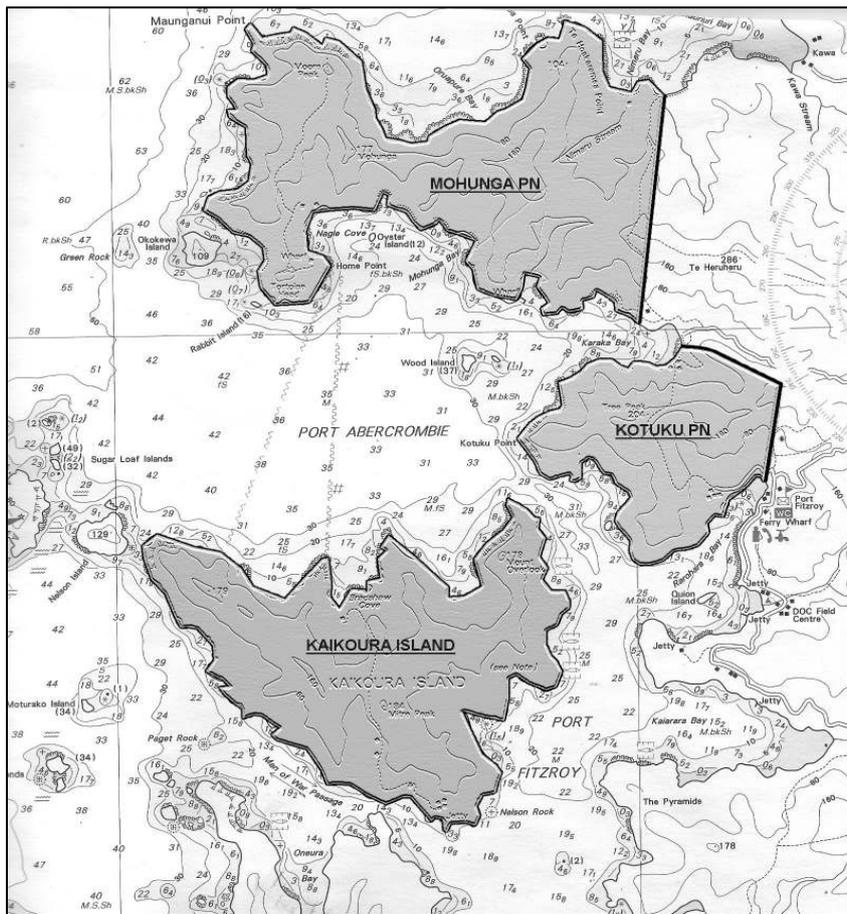


Fig 14.2 Map of the Port Abercrombie / Fitzroy area, showing areas, as proposed in 2008, for rat / feral cat eradication. Eradication attempts using aerial applications of brodifacoum have since been carried out on Motu Kaikoura and the Kotuku Peninsula. Extensive ground baiting for rodent control, and replanting with native trees, is taking place on the Mohunga Peninsula. All these areas are community-based restoration projects.

Control of feral cattle

Feral cattle were present throughout Great Barrier Island soon after European settlement, and were hunted for sport^{IX}. Feral cattle are the subject of a current Department of Conservation control campaign in the Te Paparahi area, where they are preventing vegetation recovery following the removal of goats. Eighteen animals were culled between 2008 and 2009. Although relatively few animals remain, they create extensive damage, breaking down saplings and small trees (up to 10cm diameter) for fodder.

Multiple mammal eradications – including rodents

Recently there have been several ambitious attempts to eradicate rats, feral cats and other mammals from parts of Great Barrier Island. These eradication campaigns have been initiated and funded largely by private trusts, although the Auckland Regional Council and Department of Conservation staff have been involved at all stages.

Driven by Tony Bouzaid of Glenfern Sanctuary, a mammal-proof fence with electronic surveillance was completed across the Kotuku Peninsula in July 2008. Soon after this pigs were eliminated, and in July and August 2009 two aerial applications of brodifacoum were applied. Monitoring of 906 tracking tunnels since then suggests that rodent elimination has been successful, but confirmation will require two years of monitoring. Rabbits also appear to have been eliminated within the fence. The problem of re-invasion across water, or around the fence endings at the shore, remains so long as rodents remain elsewhere on Great Barrier Island. Cats are still present, but are currently being targeted.

Motu Kaikoura Island (564 ha) was purchased in 2004 by Department of Conservation (Nature Heritage Fund), ASB Community Trust, Auckland Regional Council, and the local city councils (Auckland, Manakau, North Shore, Waitakere, Papakura and Rodney District) and placed under the management of the Motu Kaikoura Trust. The trust's main initial objective was to rid the island of existing pests. A hunting programme for feral fallow deer (*Dama dama*) and pigs (*Sus scrofa*) was initiated in 2008, and these animals have now been exterminated. Aerial bait drops for rodents took place in spring 2008. Some nearby Islands (Motuhaku, Nelson and the Grey Group) were also targetted, and may prove to be valuable pest-free refuges for sea-birds in future. Subsequent monitoring has indicated the presence of a few rats on Motu Kaikoura, but it is not known whether these are survivors or new invaders across the very narrow strait (Man o' War Channel) between the Island and the Great Barrier Island mainland. An intensive trapping and baiting programme is now in place on both sides of this channel. The islands in the nearby Broken Islands Group were likewise treated with aerial applications of brodifacoum in 2008, by the Auckland Regional Council. Ship rats appear to have been eliminated from them^x.

Thus, these three rodent eradication campaigns (Motu Kaikoura, Broken Islands (Fig 14.3) and Kotuku Peninsula) carried out in 2008 and 2009; appear to have all succeeded in eradicating the worst predator, ship rat. Mice may also have been removed from Kotuku. Rodent eradication is also planned for the the adjacent Mohunga Peninsula. However, the long-term success of these projects will depend on obtaining the funding required to maintain monitoring and prevent re-invasion from the still rat-infested Great Barrier Island mainland. While focussing on rats, the campaigns have clearly defined wider restoration goals, and have been accompanied by extensive weed eradication and native tree planting programmes. Robins have been re-introduced at Glenfern Sanctuary, and further re-introductions are possible in future. Continued monitoring of bird and rare plant populations such as Cook's scurvy grass (Nau; *Lepidium oleraceum*) on Mahuki Island, could generate future employment.

Fig 14.3 Coastal cliffs on Mahuki Island with populations of the endangered plant called Cook's scurvy grass (Nau; *Lepidium oleraceum*), which was used to provide vitamins to early sailors and hence prevent scurvy. Despite being called 'grass' it is actually a member of the cabbage family. The presence of this plant delayed the toxin drop, while opinions were sought as to the possible detrimental effects that the removal of rats could have on its continued survival.

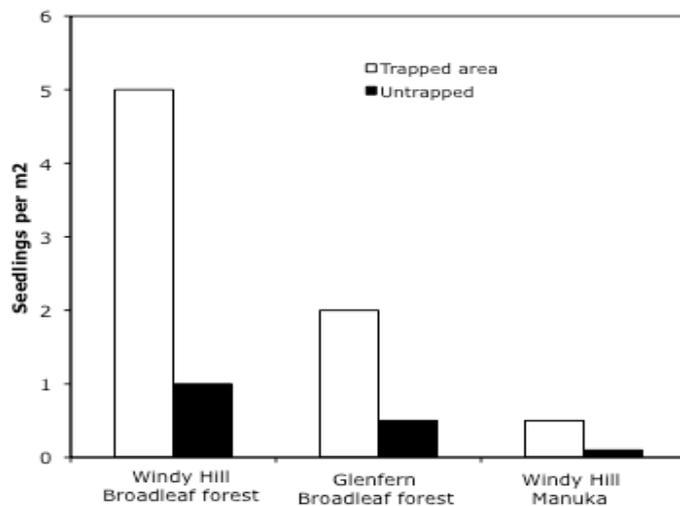


Photo: Mike Lee

Rodent / feral cat control at Windy Hill and Benthorn Farm

Rodent and cat trapping commenced at Windy Hill in 1998. Since then the area being managed for these pests has increased to 750 ha, including Benthorn Farm and 13 other landholdings. The project is one of the the most ambitious private conservation projects in New Zealand, and one of the few to have kept a careful record of its activities and the results achieved. As a consequence of these detailed records, adaptive science-based management decisions have been possible. An analysis of rat-trap-index data from 1999 to 2004^{xi} showed that trapping alone could not eliminate rats, or even keep them at levels low enough for successful breeding by small birds such as robins. Following robin introduction a twice yearly toxin pulse was added to the trapping, and this further reduced rat densities, compared to untreated control areas, as monitored in tracking tunnels. In 2008, as the area being managed increased and financial constraints began to bite, the project converted solely to toxin baits, and rodent trapping ceased. The Windy Hill/Rosalie Bay Catchment Project has facilitated much conservation research, set up and analysed independently by consultants, the universities and Landcare Research. The reduction of the rodent population has been shown to coincide with increased abundance of forest birds (see Chapter 13), reptiles and large invertebrates. Forest regeneration has also been facilitated by the reduction in rats – which are primarily herbivorous (eg. Fig 14.4)^{xii}.

Fig 14.4. The relative abundance of seedlings of nikau palm (*Rhopalosylis sapida*) in rat-trapped and untrapped areas. Modified from Samaka 2002^{xiii}.



Pest eradications on other Islands in the Hauraki Gulf

There are c. 30 islands greater than c.1 ha in the Hauraki Gulf Marine Park. Twenty one of these are now free of mammalian pests (Table 14.1). The best known of these are Hauturu (Little Barrier Island) (3.083 ha), Red Mercury (202 ha), Cuvier (196 ha) and Tiritiri Matangi (197 ha). While Hauturu can be visited only by permit, Tiritiri Matangi is an ‘Open Sanctuary’ visited by thousands of tourists every year, and allowing free access to beaches by boating parties. Despite this, in over a decade of operation as an open sanctuary mice and rats have not re-invaded. Rangitoto-Motutapu (3882 ha) had aerial applications of brodifacoum in 2009, and may soon be declared the largest Open Sanctuary free of mammalian pests in the Gulf. With the large populations of Auckland (and Waiheke Island) close-by, good existing infra-structure and an excellent ecological guide-book^{xiv}, this island complex seems set to become a major tourist attraction and a source of biodiversity renewal in the Hauraki Gulf.

Table 14.1 Summary of pest-status of islands in the Hauraki Gulf Marine Park. **Yellow** indicates that mammalian pests were never present or have been eradicated. **Blue** indicates eradications in progress. Great Barrier Island is emphasised in bold text. The off-shore Great Barrier Islands, Motu Kaikoura and the broken Islands are *not* given separate island status here.

Island	Size (ha)	Mammalian pests	Selected key species.
Hauturu/Little Barrier	3,083	Eradicated	Kiwi, tuatara, kakariki, saddleback, stitchbird, kaka, Cook's petrel, kokako, wetapunga.
Red Mercury Island (Mercury Islands Group)	202	Eradicated	Tuatara, little spotted kiwi, saddleback, Red crowned kakariki; burrowing seabirds.
Tiritiri Matangi	197	Eradicated	Little spotted kiwi, kokako, NI robin, diving petrel, grey faced petrel, saddleback, tuatara, stitchbird & takahe.
Cuvier (plus 13 associate stacks and rocks)	196	Eradicated	Tuatara; Saddleback; Red-crowned kakariki; moko skink; Suters skink; Mercury Island tusked weta.
Motuihe	195	Eradicated	NZ dotterel & saddleback.
Rakino	146	Eradicated	
Aldermen (Ruamaahua) Islands Group	113	Eradicated	Ornate skink; tuatara; Duvaucel's gecko; burrowing seabirds.
Stanley Island (Mercury Islands Group)	100	Eradicated	Mercury Island tusked weta, Kaka; Saddleback; Red-crowned kakariki.
Motuora	85.5	Never had rats	NI brown kiwi, whitehead, grey faced petrel, diving petrel & Duvaucel's gecko.
Motukorea/ Browns Island	57.5	Eradicated	NZ dotterel, <i>Euphorbia glauca</i> .
Pokohinau/Burgess (Mokohinau Islands Group)	52	Eradicated Kiore 1990 Goats 1973	Red crowned kakariki; bellbird. Seven species of lizard (incl. endemic Mokohinau gecko) and several spp. of burrowing seabird: grey-faced petrel, little shearwater, fluttering shearwater, white faced storm petrel.
Fanal/Motukino (Mokohinau Islands Group)	73	Eradicated Kiore 1997	<i>Lepidium oleraceum</i> , <i>Tupeia antarctica</i> and other rare and endemic plant spp. Duvaucel's gecko, moko skink. Burrowing seabirds (see above).
Trig/Atihau (Mokohinau Islands Group)	16	Eradicated Kiore 1990	Four spp. of lizard and several spp. of burrowing seabirds.
Hokoromea (Mokohinau Islands Group)	10	Eradicated Kiore 1990	Four spp. of lizard and several spp. of burrowing seabirds.
Groper Rock/Tatapihi	2.8	Never had rats	Robust skink; Town's skink; Mokohinau gecko.

Rock stacks and islets of the Mokohinau Group (c. 25)	c. 170	Eradicated 1990, but some never had rats.	Mokohinau stag beetle. Town's skink. Mokohinau gecko. <i>Placostylus hongii</i> . Grey faced petrels, little shearwater, fluttering shearwater, white faced storm petrel.
Double Island (Mercury Islands Group)	33	Eradicated	Mercury Island tusked weta. Lizards.
Korapuki Island (Mercury Islands Group)	18	Eradicated	Robust skink; Whitaker's skink; Suter's skink, Mercury Islands tusked weta. Duvaucel's gecko.
Middle Island (Mercury Islands Group)	13	Never had rats	Burrowing seabirds, tuatara, Middle Island tusked weta, 10 spp. of lizard, tuatara.
Green Island (Mercury Islands Group)	3	Eradicated	7 spp. Lizards, Suter's skink.
Taungamaro/ Beehive	0.9	Eradicated	NZ dotterel.
Rangitoto	2,321	Norway rats, ship rats, mice, hedgehogs, stoats, feral cats & rabbits.	Egg laying skink, 200 species of native trees & flowering plants, including 40 kinds of fern & several orchid species.
Motutapu	1561	Norway rats, ship rats, mice, hedgehogs, stoats, feral cats & rabbits.	NZ dotterel & egg laying skink.
Moturekareka	19	Mice.	Little blue penguin.
Te Hapua/Saddle	6	Mice.	Grey faced petrel, little blue penguin.
Kohatutara	1.1	Mice.	White fronted tern.
Motutara	4.5	Mice.	White fronted tern.
Rakitu/Arid ^{xv}	230	Rodents.	Ni weka, little blue penguin & grey faced petrel.
Aotea/Great Barrier <i>Note that Motu Kaikoura and the Broken Islands (mammalian pest eradications 2009) are not given separate status here.</i>	27,400	Ship rats, kiore, mice, pigs, rabbits, feral cats.	Pateke, chevron skink (one of 13 spp of lizards), Hochstetter's frog, kaka, New Zealand dotterel, black petrel. <i>Lepidum oleraceum</i> and several other threatened plants. Three endemic plant species.
Kawau	2,023	Ship rats, mice, possums, wallabies, feral cats, stoats.	North Island brown kiwi, North Island weka.
Waiheke	9,324	Ship rats, Norway rats, mice, hedgehogs, stoats, goats, pigs, feral cats	NZ dotterel. Green gecko.

At c. 27,400 ha Great Barrier Island considerably exceeds any of the other Hauraki Gulf islands in size, and is more than twice the area of the largest island from which rats have yet been eradicated (Campbell Island 11,300). The difficulties involved with size, rugged topography, and a large scattered resident human population, some of whom are opposed to the use of poisons, are great^{xvi}. Because of the toxin debate, the challenge will be to find other methods to eradicate mammalian pests on Great Barrier Island. However, the evidence remains: the Department of Conservation has successfully eradicated mammalian pests from over 100 off-shore islands and the size of island eradicated has progressively increased and the equipment and technological expertise are all available.

The rat problem - effects of rodents on island ecosystems

Three species of rat were formerly present throughout mainland New Zealand. Ship rats (*R. rattus*) and Norway rats (*R. norvegicus*) are still abundant and are considered to be the most detrimental of all invasive species^{xvii}. The kiore (or Pacific rat, *R. exulans*) is slightly smaller and less arboreal than the ship rat (*R. rattus*) and is now probably confined to off-shore islands. Kiore is sometimes thought to be less of a problem. This is not so: in fact kiore, being present in New Zealand for much longer than ship rat, have probably been responsible for twice as many bird extinctions (23 species) as have ship rats^{xviii}. Confusion can arise in identification, because the ship rat has three distinct colour morphs, and juveniles of one of these (*R.r. alexandrinus*), are easily mis-identified as kiore. There is extensive published work on the ecology of all these species, and mice (*Mus musculus*) in New Zealand^{xix}, and research demonstrating their detrimental effects on island biota worldwide.^{xx}

The largest rat, *R. norvegicus*, is present on Waiheke, but never established on Great Barrier Island; the other three rodents are abundant on the Island. Being omnivorous, they are all predators on birds, lizards, invertebrates, seeds and seedlings, thus causing ‘cascading’ influences on ecosystem functions.^{xxi}

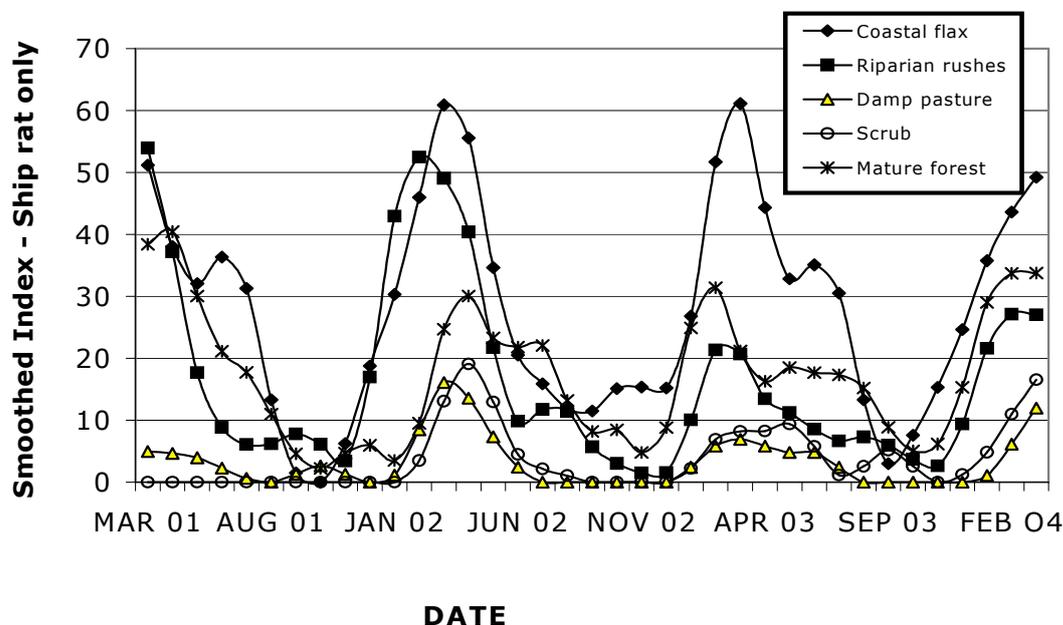
The influence of rats on forest regeneration is less well known than nest predation, but rodents are primarily herbivorous, and vast numbers of tree seeds and other plant parts are eaten^{xxii}. The regeneration of at least eleven tree species has been seriously impaired on islands around New Zealand by the presence of rats^{xxiii}, to the extent that some may have been eliminated from some Hauraki Gulf islands. The vegetation structure and composition has certainly changed in consequence.

Data on rat abundances from Windy Hill, Okiwi and Awana, demonstrates the annual cycle of abundance (Fig 14.5), with low values in spring (September-November) and peaks usually in late summer or autumn (March – May). Peaks vary by up to several weeks from place to place and year to year. Over the three years studied rat peaks were greatest in coastal flax, river-side rushes and a remnant of mature forest in a stream gully. Scrub, covering so much of the Great Barrier Island landscape (54%, Chapter 9) appears to have relatively low rat densities. This observation, supported by results from Windy Hill (Fig 14.4), suggests that rats are having greater impacts in mature forest, where fruit and insect food is abundant, than in the scrub, and indicates where control efforts should be concentrated.

Although not shown here, kiore and mice peaks tend to be off-set with regard to ship rats. The implied competitive hierarchy between the species has implications for their

eradication^{xxiv} – at least in grassland or river-side (riparian) rushes mice could ‘explode’ if ship rat and kiore were eliminated.

Fig 14.5 The annual cycle of rat abundance at Awana, also showing the relative abundances in different types of vegetation cover^{xxv}. The index is catch per 100 trap/nights^{xxvi}.



The actual number of rats per hectare present on Great Barrier Island is difficult to estimate from trapping because the proportion of the total population trapped is never known, and numbers also fluctuate seasonally. However, from the many years of trapping at Windy Hill, and Awana, it is possible to make some estimates. At Windy Hill over four years of trapping in mostly scrub and forest habitats, 11,548 rodents were caught, equivalent to 6.4 rodents/ha/year. Similar calculations from trapping in mostly scrub and grassland at Awana gave 31 rodents/ha/year. Both these figures must underestimate the numbers actually present. Using these figures, and taking into account the relative cover of the different vegetations throughout Great Barrier Island (Chapter 9) provides an estimated total rodent population of at least 286,000. This figure can be regarded as a minimum; the true figure may be several times this, at least in the autumn. This is equivalent to saying that, no-matter where you are on Great Barrier Island, on average; you are never more than 16m from the nearest rodent!

Effects of feral cats

Feral cats (*Felis catus*) are recognized as the third worst predator (after humans and kiore) of New Zealand birds, having contributed to the extinction of twenty one bird species and an unknown number of reptiles^{xxvii}. For example, on Stephens Island, one of the last populations of the piopio (*Turnagra capensis*) of c. 1000 birds was wiped out by cats in four years (1894-8). Cats were probably established on Great Barrier Island soon after 1840. On the mainland, feral cats mainly eat rabbits, rats and mice, but, on islands they prey on whatever is available, often birds. For example, of 94 cats examined on Little Barrier Island (Hauturu) in 1961, 39% contained evidence of kiore but 71% had evidence of birds^{xxviii}. Cat eradication is a highly emotive issue because of the large number of people who keep them as domestic pets. Thus it is necessary to recognise two integrating states:

Domestic cats: are those which normally live in or close to a household and are regularly fed by their owner. While these animals undoubtedly account for a large number of birds and lizards^{xxix} and can travel considerable distances in search of prey, they are mainly an urban problem. Some of these cats become ‘wild’ but still return to domestic settings for a proportion of their food.

Feral cats: are cats which no longer seek human contact – in fact they shun it. These cats get all of their food by hunting. They are born and raise their litters in the wild. Feral cats may specialise, and become proficient at catching particular prey. Their devastating effects on bird populations on islands is well documented^{xxx}. On islands where feral cats have been eradicated, the subsequent increases in in populations of surviving bird species, and the success of re-introductions of species which had disappeared, are evidence of the effects of cats. In the Hauraki Gulf feral cats have been exterminated on Little Barrier Island (Hauturu), Tiritiri Matangi, Motuihe, Cuvier and the Mercury group, and are currently in process on Rangitoto/Motutapu,

Data on feral cats on Great Barrier Island is summarized in Table 14.2. These figures give very little indication of the scale of the problem, although they do suggest a very considerable investment by DOC designed to protect the Okiwi brown teal flocks. Cats have also been shot (and trapped) in the Awana beach area since 2004, and it is estimated that c. 300 have been killed over a 5-year period. Thus probably c. 200 feral cats are currently being shot annually. Given the relatively small size of the areas represented in Table 14.2 and at Awana, it seems safe to assume that there are many more roaming the island. Direct scaling-up for area gives a figure of 1176, or c. 4 cats/km², but this takes no account of cat longevity and must considerably underestimate the actual number of feral cats on Great Barrier Island. This feral cat population is self-sustaining at present, and is a recognized threat to at-risk populations of both brown teal and black petrel.

If all feral cats could be eliminated by Department of Conservation and other organisations, there would be a risk of re-introduction from domestic cats, especially from those owned by casual visitors to the Island. Controlling such further input to the feral cat population by limiting cat ownership to permanent residents, or requiring sterilization, would certainly be a step in the right direction for conservation of biodiversity on Great Barrier Island. Models are available – for example the successful micro-chipping of domestic cats and control of feral cats on Fraser Island^{xxxii}.

Table 14.2. Data on cat trapping from Okiwi Basin^{xxxii} and Windy Hill.

Location/Year	Pre 2004	2004 - 2005	2005 - 2006	2006 - 2007	2007 - 2008	Totals
Okiwi Basin	366	115	130	99	100	695
Windy Hill	102	32	27	22	8	198

Rabbits

Rabbits are widespread on Great Barrier Island, especially on the farmland and dunes on the eastern side. Their environmental damage to dunes (especially eating pingao, *Desmoschoenus spiralis*; (Chapter 9, Fig 9.17), and on farm-land, is well known. Rabbits are a problem

debarking saplings and eating seedlings in restoration projects, and they have invaded bush areas adjacent to grassland, where they similarly inhibit natural regeneration.

In 2004 Department of Conservation destroyed about 4000 rabbits in the Okiwi basin. Since then c. 1000 are shot annually (for cat bait). An additional 1000 were removed in 2009 for bait used in cat eradication on Rangitoto – Motutapu.

Strong antagonism to Auckland Regional Council's suggested release of RHD (*Calisi virus*) to control rabbits was expressed at a public meeting on Great Barrier Island in 2007. Despite this, the virus reached the island soon after, but seems to have knocked down rabbit numbers only for a season.

The interaction between rabbits, cats and brown teal suggests that any rabbit reduction will need to be synchronised with cat control, to minimise the risk of cats 'prey switching' to teal or other birds.

Pigs

Pigs have recently been eliminated from the Kotuku Peninsula and Motu Kaikoura, and are controlled at Windy Hill. Elsewhere, evidence of their presence occurs in much of the public conservation state and other parts of Great Barrier Island. There appear to be no data on which an estimate of their numbers can be made, but permitted pig hunter's return's suggest that 80 -100 are culled annually.^{xxxiii}

The damage caused by pigs is incalculable because there has been inadequate research in New Zealand. However, by comparison with studies in Australia and Hawaii, it seems likely that it is considerable. As early as 1896, Kirk claimed that the pig was responsible for the eradication of tuatara on the New Zealand mainland. In the 1930s pigs almost exterminated the endemic Buller's shearwater (*Puffinus bulleri*) from it's only nesting colony on the Poor Knights Islands. Only after elimination of pigs did shearwater numbers recover. Various plant species are also known to have been severely impacted by pigs, including rare orchids and the common bracken fern. Their effect on forest regeneration is clear from inspection. Large areas of ground cover, including tree seedlings and saplings, are regularly uprooted. On hillsides clad in regenerating scrub, this causes soil instability and loss, further delaying their return to a forest canopy. Because they are hunted for energetic sport and food by some residents, and visitors, any future pig control measures will necessarily involve community consultation.

Summary – Terrestrial mammals and mammalian pests

- The only indigenous terrestrial mammal known to be present on Great Barrier Island is the endangered long-tailed bat.
- The extant introduced herbivores are rabbits and wild cattle. Fallow deer are currently being exterminated on Kaikoura Island.
- Feral cat is the only extant introduced carnivore.
- Extant introduced omnivores are the three rodents (ship rat, kiore, and mouse) and pig.
- Rodents, especially ship rat, are the most serious environmental pests

- Wallaby and feral goat have been exterminated, although the risk of re-introduction from farmed goats remains.
- Norway rat, possum, stoat, weasel, ferret, hedgehog and red deer have never been present on Great Barrier Island, and the absence of these serious pests probably accounts for the survival on the Island of some species which are endangered or extinct elsewhere.
- All mammalian pests are currently being eliminated from Motu Kaikoura, the Broken Islands and the Kotuku Peninsula, with the latter protected by a pest-proof fence.
- A decade of rodent trapping and monitoring at Windy Hill, and the application of different toxin regimes, has increased our understanding of the efficacy of these techniques.
- Research at Windy Hill has demonstrated the biodiversity gains (birds, lizards, invertebrates and vegetation) achieved by reducing rodent numbers.
- Twenty-one of the 30 islands > 1ha in the Hauraki Gulf Marine Park are now free of mammalian pests.
- The largest mammalian pest-free island in the Hauraki Gulf is Little Barrier/Hauturu (3083 ha), but this will be exceeded by Rangitoto/Motutapu (3882 ha) if the current eradication programme there succeeds, when it will become an 'Open Sanctuary'.
- Tiritiri Matangi Island has been free of rats since 1993, and operated it as Open Sanctuary. Despite visits from thousands of tourists every year, rats have not re-invaded. The coastline is monitored, but inconvenient biosecurity measures are not imposed.
- Research on pig impact and numbers.
- Research on rat population cycles in different vegetation types on Great Barrier Island provides evidence of when and where these rodents are most susceptible to control.
- Feral cats pose a documented risk to brown teal and black petrel.
- Feral cats are controlled at Windy Hill (by the Windy Hill/Rosalie Bay Catchment Trust), and in the Okiwi Basin (by Department of Conservation), but there are probably > 4 cats/km² over the Island as a whole.
- Rabbits are a problem on coastal dunes, and are increasingly invading forest, where they inhibit regeneration.
- The rabbit population interacts with its main predator (cat) in a complex food-web involving brown teal.

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- i Halema Jamieson, DOC, Port Fitzroy. Personal communication.
- ii DOC., Port Fitzroy. *File ref: NHS-04ii*
- iii Veblen, T.T. & Stewart, G. H. 1982. *The effects of introduced wild mammals on New Zealand forest. Annals of the American Association of Geographers* 72: 372-97.
- iv Kaikoura is home to kaka and nook skink. Brown teal use it as a feeding ground (DOC website).
- v Rakitu has weka, little blue penguins, grey faced (and possibly other) petrels (DOC website).
- vi Mahuki Island has the endangered Cook's scurvy grass (*Lepidium oleraceum*).
- vii Wright, E. A. & Cameron, E. K. 1988. *Botanical features of northeastern Great Barrier Island, Hauraki Gulf, New Zealand. Journal of the Royal Society of New Zealand.* 15 (3): 251-278.
- viii There was ongoing consultation with the community, Iwi and landowners throughout the goat eradication project. Goats were removed from Te Paparahi in the north by NZFS cullers between 1986 and 1992. These cullers continued working south down the island during the 1990's. The Auckland Regional Council became involved in the program in the late 1990's and funded work on private land in the south of the island. Joint DoC/ARC contracts were carried out by Prohunt NZ and Biocare Aotea. The last goat was shot in the Rosalie bay area in 2005.
- ix In: Goulding, J. H. 1983. *Fanny Osborne's flower paintings*. Pp. 04. Heinemann.
- x Mike Lee, personal communication.
- xi Ogden, J. & Gilbert, J. 2005. *Recent trapping results from Windy Hill and Benthorn Farm, Great Barrier Island: 1999 – 2004*. Unpublished Report.
- xii Ogden, J & Gilbert, J. 2009. *Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on Great Barrier Island, New Zealand. Biological Invasions* 11: 1705-1717.
- xiii Samaka, D. M. 2002. *The benefits and costs of community based conservation: a case study on Great Barrier Island, New Zealand*. Unpublished M. Sc. Thesis. University of Auckland.
- xiv Wicox, M. D. (Ed.). 2007. *Natural history of Rangitoto Island*. Pp. 192. Auckland Botanical Society. Auckland.
- xv DOC is considering Rakitu for pest eradication after 2013. However there are Treaty settlement issues to resolve also.
- xvi Ogden, J & Gilbert, J. 2009. *Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on Great Barrier Island, New Zealand. Biological Invasions* 11: 1705-1717.
- xvii (Atkinson 1985; Atkinson & Towns 2001; Innes 2001).
- xviii Tennyson, A. & Martinson, P. 2006. *Extinct birds of New Zealand*. Pp. 180. Te Papa Press, Wellington.
- xix King, C. M. (Ed.) 1995. *The handbook of New Zealand mammals*. Pp. 600. Oxford University Press. Auckland, New Zealand.
- xx See: 'Invasive Rodents on Islands' *Biological Invasions* (2009) vol. 11.
- xxi Campbell, D. J. & Atkinson, I. A. E. 2002. *Depression of recent tree recruitment by the Pacific rat (Rattus exulans Peale) on New Zealand's northern off-shore islands. Biological Conservation* 107: 19-35.
- xxii Best, L. W. 1969. *Food of the roof rat (Rattus rattus L.) in two forest areas of New Zealand. New Zealand Journal of Science.* 12: 258-267. Dowding, J. E. & Murphy, E. C. 1994. *Ecology of ship rats (Rattus rattus) in a kauri (Agathis australis) forest, in Northland, New Zealand. New Zealand Journal of Ecology* 18: 19-28.
- xxiii Campbell, D. J. & Atkinson, I. A. E. 1999. *The effect of kiore (Rattus exulans Peale) on recruitment of indigenous trees on northern offshore islands of New Zealand. Journal of the Royal Society of New Zealand* 29: 265-290. Campbell, D. J. & Atkinson, I. A. E. 2002. *Depression of recent tree recruitment by the Pacific rat (Rattus exulans Peale) on New Zealand's northern off-shore islands. Biological Conservation* 107: 19-35.
- xxiv Ogden, J & Gilbert, J. 2009. *Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on Great Barrier Island, New Zealand. Biological Invasions* 11: 1705-1717.
- xxv Ogden, J & Gilbert, J. 2009. *Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on Great Barrier Island, New Zealand. Biological Invasions* 11: 1705-1717.
- xxvi Cunningham, D. M & Moors, P. J. 1996. *Guide to the identification and collection of New Zealand rodents*. Pp. 24. Department of Conservation, Wellington, New Zealand.
- xxvii Tennyson, A. & Martinson, P. 2006. *Extinct birds of New Zealand*. Pp. 180. Te Papa Press, Wellington.
- xxviii Marshall, W. H. 1961. *A note on the food habits of cats on Little Barrier Island, New Zealand. New Zealand Journal of Science* 4: 822-824. (see summary Table in King 1995)
- xxix Research of Dr Y. van Heezik reported in *GBI Environmental News* 6, 2006.
- xxx Veitch, C. R. 1985. *Methods for the eradication of cats from off-shore islands in New Zealand*. In: Moors, P. J. (Ed.). *Conservation of island birds: 125-141*. International Council for Bird Preservation Technical Publication No. 3.
- xxxi T. Bouzaid: Report to Great Barrier Community Board. 26th September 2000.
- xxxii Jo Sim; DOC
- xxxiii George Wilson (DOC)