

¹DSIR Land Resources, Private Bag, Lower Hutt, New Zealand.

²DSIR Land Resources, Private Bag, Nelson, New Zealand.

³Department of Conservation, Private Bag 8, Newton, Auckland, New Zealand.

THE DIET OF FERAL CATS (*FELIS CATUS*) ON RAOUL ISLAND, KERMADEC GROUP

Summary: Feral cats became established on Raoul Island some time between 1836 and 1872; the prey available to them included a great variety of nesting seabirds, few of which are present now, landbirds and kiore (*Rattus exulans*). Norway rats reached the island in 1921, providing additional prey for cats, but also another potential predator of seabirds. The diet of cats is described from guts and scats collected between 1972 and 1980. Rats are the main food, with land birds second in importance, and seabirds are now a minor item. More than 90% of the rats eaten by cats are kiore although more Norway rats than kiore are trapped. Eradicating cats from Raoul Island is feasible but because Norway rats too are important predators of birds on islands, it is likely that eradicating cats without also eradicating Norway rats will do little to restore the diversity of bird species on Raoul Island, although the densities of a few species now present might be increased.

Keywords: Feral cat; *Felis catus*; kiore; *Rattus exulans*; Norway rat; *Rattus norvegicus*; diet; Raoul Island; Kermadecs.

Introduction

When populations of feral cats (*Felis catus*) become established on oceanic islands they usually find as prey a few introduced mammals, some landbirds and various seabirds (Fitzgerald, 1988). Raoul Island in the Kermadec Group is no exception. When cats were introduced last century the introduced kiore (*Rattus exulans*) was the only mammalian prey though many birds were available. Land birds present then included the Kennadec parakeet (*Cyanoramphus novaezelandiae cyanurus*), an undescribed pigeon, tui (*Prothemadera novaeseelandiae*), and sacred kingfisher (*Halcyon sancta*); seabirds included at least five species of petrels and three species of terns (Merton, 1970).

Norway rats (*Rattus norvegicus*) were introduced in 1921. Now cats and rats are common, the local pigeon is extinct, parakeets are represented only by stragglers from the nearby Herald Islets, and the only common seabird is the colonial-nesting sooty tern (*Sterna fuscata*) which may be threatened by cats and rats (Taylor, 1979).

Raoul Island, excluding the 111 ha Meteorological Station, was declared a Fauna and Flora Reserve in 1934. Programmes are being undertaken to eradicate introduced plants and animals. Goats (*Capra hircus*) were finally eradicated in 1984 (Parkes, 1990) and efforts are being made to eradicate about a dozen species of plants, of which Mysore thorn (*Caesalpinia decapetala*) is most important (Devine, 1977; Sykes, 1977). Eradication of cats is also considered. The diet of cats is described here from gut contents of cats killed

and autopsied during expeditions in 1972, 1973 and 1974 and from scats (droppings) collected by visitors to Raoul Island in 1972, 1975, 1978, and 1980, in an attempt to better predict the consequences of eradicating cats from Raoul Island. Names of plants, birds and mammals follow Sykes (1977), Turbott (1990) and King (1990) respectively.

Description of Raoul Island

Raoul Island (29°15'S, 177°52'W), almost 1000 km northeast of New Zealand (Fig. 1), is the largest of the Kermadec Islands, with an area of 2941 ha and a maximum height of about 520 m. It is of volcanic origin and is still volcanically active. The island is largely covered in forest, dominated by Kermadec pohutukawa (*Metrosideros kermadecensis*). In the drier forest below about 244 m the understorey is characterised by *Myrsine kermadecensis*, but in the wetter forest above this elevation the understorey is formed by *Ascarina lucida* var *lanceolata* and to a lesser extent *Melicytis ramiflorus*. The flora is detailed by Sykes (1977).

The avifauna and its changes are well documented by Cheeseman (1888, 1890), Iredale (1910, 1912, 1914), Guthrie-Smith (1936), Sorensen (1964), and the Ornithological Society of New Zealand expeditions in 1964 and 1966-67 (Edgar, Kinsky and Williams, 1965; Merton, 1968, 1970; Merton and Veitch, 1986). It includes about five species of petrels that breed, or bred, on the island, three terns, the red-tailed tropicbird (*Phaethon rubricauda*), pukeko (*Porphyrio porphyrio*),

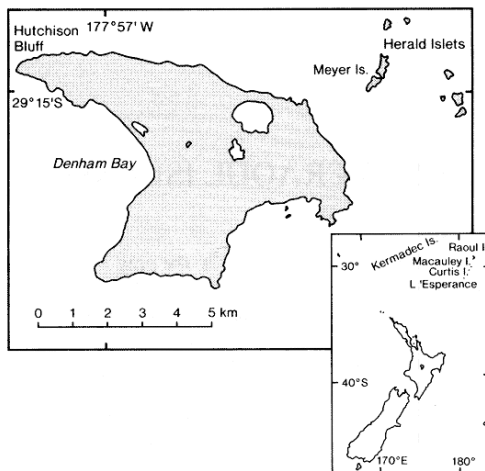


Figure 1: The Kermadec Islands in relation to New Zealand, showing Raoul Island and places mentioned in the text.

grey duck (*Anas superciliosa*), and four native land birds - the Kermadec parakeet, pigeon, tui and kingfisher - plus about six species of European passerine that have colonised from New Zealand.

Evidence of early Polynesian settlements has been found on Raoul Island (Anderson, 1979). They probably introduced kiore, which were already on Macauley Island, and probably on Raoul Island too, when Europeans discovered the Kermadec Islands in 1788 (Cheeseman, 1888). During the 19th century many people attempted to settle on Raoul Island (Smith, 1887; Straubel, 1954; Morton, 1957; Haigh, 1968). The first settlers arrived in late 1836 and about eight families lived on the island at various times over the next 36 years. Some families stayed only a few years but others stayed for about 10 years.

When Tom Bell and his family arrived on Raoul Island in 1878 feral cats and kiore were already present (Morton, 1957). Some of the earlier settlers probably brought pet cats or obtained them from visiting ships as pets and to control kiore, which were a pest. Cats were probably introduced early, rather than late, in the period of settlement. In 1836 Captain Rhodes found "an abundance of parrots, pigeons and other birds on the island" (Straubel, 1954, p. 35), but by 1887 the pigeon, and other birds, had become extinct and cats had "become wild and increased very much" (Smith, 1887, p.23).

Other species of rats did not become established on Raoul Island during the period of settlement, probably because there was no wharf and all supplies were landed by small boat. Norway rats became established in 1921

when the schooner *Columbia River* was wrecked there (Watson, 1961; Haigh, 1968).

Methods and Material

Cats were trapped throughout Raoul Island using Lane Ace gin traps in spring 1972, winter 1973 and spring 1974; details of the method are given by Veitch (1985). Traps were baited with fresh fish and replaced every four days. Cod-liver oil was added to the baits after two days. Cats were also hunted with dogs and shot. Animals were autopsied in the field and skulls saved to determine their age by tooth replacement and skull shape; details were recorded as described by Fitzgerald and Veitch (1985).

In 1972, contents of the stomach, intestine and rectum of cats killed were preserved in alcohol and brought back to New Zealand for detailed analysis. In 1973 and 1974 stomach contents were identified in the field; this provided less detailed information on the identity and numbers of prey.

Scats were collected in 1972, 1975, 1978 and 1980. All scats in 1978 and some in 1980 were stored and later examined individually; other scats collected on each trip were stored together and examined as a pooled sample. Scats were soaked in a weak sodium hydroxide solution, sorted in water, and the bones, teeth and feathers were retained and identified by comparison with reference material. Bones of blackbirds (*Turdus merula*) and song thrushes (*Turdus philomelos*) could not be distinguished and are listed as blackbird/thrush. Blackbirds and thrushes are both common (Merton and Veitch, 1986) and the blackbird/thrush material probably includes both species. Kiore and Norway rats were distinguished on the size of teeth and bones. The number of individual birds present was counted from distinctive bones; rats were counted from teeth, especially incisors and the first molars. Bones and teeth from the left and right sides of the body were counted separately and the number of the most frequent item was used as the minimum number of individuals eaten.

Results of the analyses of guts and of individual scats in 1978 and 1980 are given as percentages of guts or scats containing each prey. In addition, for the 1972 guts and for the individual and pooled samples of scats the minimum number of individuals of each prey was counted.

Results

In 1972, 1973, and 1974 a total of 101 cats (68% males) was killed (Table I); 83% were trapped. Sixty percent were striped tabbies and 40% were black. Eight of the 61 tabbies and 11 of the 40 black cats had white hair on the ventral surface. Three-quarters of the cats were

Table 1: Sex and age structure of 101 cats killed and autopsied on Raoul Island 1972-74. In 1974 six additional cats were killed but not autopsied.

Sex	Age	1972	1973	1974
Male	Juvenile	1	1	1
	Subadult	6	1	3
	Adult	37	3	16
Female	Juvenile	2	5	0
	Subadult	2	1	3
	Adult	13	2	4
Total		61	13	27

adult, based on skull characters, and most of them were sexually mature. One adult male still had small testes; no subadult males were sexually mature and only one subadult female was pregnant. Eight of 17 adult females caught in spring were pregnant.

The diet of cats is described from: the gut contents of 61 cats and a pooled sample of scats collected in August-October 1972; 12 cats examined in the field in May-July 1973, and 26 in September-November 1974; a pooled sample of scats collected in January 1975; 11 scats collected in January-February 1978; and 27 individual scats and two pooled samples of scats collected in November 1980. Cats were trapped and scats were collected all over the island.

The gut contents of cats killed between late August and early October 1972 contained predominantly the remains of rats (86% occurrence); bird remains were present in 35% and insects (mostly blowflies) in 58% (Table 2). Eighty-seven individual rats were counted, and of 80 identified to species 92% were kiore. The remains of three of the six Norway rats included molar teeth; two had unworn teeth of young rats and one had worn teeth of an older animal. All of the bird remains identified were passerines, predominantly tui, but also included blackbird/thrush and starling (*Sturnus vulgaris*). The large numbers of blowflies found in cat guts were probably eaten with the bait. They were found as often in the rectum as in the stomach of trapped cats, but were not found in scats. Three guts contained only insect remains - one contained just a blowfly while the other two contained large numbers of emerging dragonflies. Two female fleas, *Pygiopsylla phiola* Smit, usually found on rodents, were found in guts; one in an intestine with remains of three kiore, and the other in a stomach with remains of a tui.

Thirteen cats were killed in May-July 1973, and gut contents of 12 were examined in the field. Eleven contained remains of prey; all contained rats and one also had the remains of a bird. Of 33 cats killed in spring 1974, 27 were autopsied and the gut contents of 26 recorded. Only seven cats (27%) contained food; one had remains of a rat, one had a fledgling tui and a blackbird or thrush, three had blowflies, one had black hair (perhaps from the cat) and one had unidentified flyblown material, that might have been bait.

Table 2: Gut contents of 57 cats killed 26 August-6 October 1972. Another four cats had no prey in their guts.

	Occurrence (% of guts)	No. of individuals
Mammals		
Total	88	
<i>Rattus</i> spp.	86	87
<i>R. exulans</i>	68	74
<i>R. norvegicus</i>	9	6
Pig	2	1
Goat	2	1
Birds		
Total	35	26
Tui	18	10
Blackbird/thrush	2	1
Starling	2	3
Unidentified adult	5	3
Unidentified juvenile/nestling	14	9
Insects		
Total		58
Insects other than blowflies		
Total		19
Dragonfly	5	many
Weta	5	9
Beetle	5	4
Blowfly	40	98
Rea	4	2
Unidentified insect	5	?
Fish bait	12	
Cat claws	4	
Grass	23	

The ratio of rats to birds in the pooled sample of scats in 1972 was similar to that in the guts collected at the same time; 68 rats and 16 birds were identified in the scats and 87 rats and 26 birds in the guts. The birds in the scats included one shining cuckoo (*Chrysococcyx lucidus* - identified from leg bones and feather), a Kermadec little shearwater (*Puffinus assimilis kermadecensis* - from quadrate bones) and a large bird, probably a grey duck (from tibia). The pooled sample of scats collected in January 1975 and in November 1980 contained rats, again almost entirely kiore and some of the same passerines identified in the 1972 material (Table 3).

Rat remains were found in most of the scats collected and examined individually in January-February 1978 and in November 1980 (Table 4), and were mainly kiore. Birds, mainly introduced passerines, were most common in the November 1980 samples (Table 4). They were present in nearly 60% of the scats in November 1980 and formed a third of the vertebrates eaten. In addition to the usual passerines, the birds included a sooty tern in each of two scats. One of these scats was collected close to the sooty tern colony at Denham Bay and the other on the track above Denham Bay.

Table 3: Number of individual prey identified in pooled samples of cat scats collected in 1972, 1975 and 1980. The 1975 unidentified bird category includes 3 unidentified passerines and one unidentified seabird.

		Aug-Oct 1972	January 1975	November 1980
Mammals				
	<i>Rattus</i> spp.	68	24	23
	<i>R. exulans</i>	63	22	23
	<i>R. norvegicus</i>	5	2	0
Birds				
	Total	16	7	8
	Tui	2		3
	Blackbird/thrush	3	2	3
	Starling	2	1	1
	Finch, unidentified	1		
	Shining cuckoo	1		
	Kermadec little shearwater	1		
	Grey duck?	1		
	Unidentified	5	4	1
Insects				
	Cicada	2 adult 11 nymphs		1 adult

Table 4: Contents of 11 cat scats collected in January-February 1978 and 27 scats collected in November 1980.

	January-February 1978		November 1980	
	Occurrence (% of scats)	No. of individuals	Occur- rence (% of scats)	No. of indi- viduals
Mammals				
	<i>Rattus</i> spp.	100 34	89	36
	<i>R. exulans</i>	82 27	74	30
	<i>R. norvegicus</i>	18 5	7	2
Birds				
	Total	36 4	59	20
	Tui	0 0	11	3
	Blackbird/ thrush	9 1	7	2
	Starling	9 1	15	4
	Sooty tern	0 0	7	2
	Unidentified passerine	18 2	30	9
Insects				
	Total	27 3	37	15
	Dragonfly	18 2	7	2
	Unidentified insect		11	3
	Cicada	9 1	19	10

Rats were the most frequent prey in all the samples (both guts and scats) and of 259 individual rats identified to species, 239 (92.3%) were kiore; the ratio of kiore to Norway rats varied little between samples. Although birds were less important than rats in the cats' diet, both in terms of frequency of occurrence and

number of individuals, five species were identified in the material, plus blackbirds and/or song thrushes, a probable grey duck, and an unidentified finch. The birds were mainly tui (18 individuals), starling (11) and blackbird/thrush (12), with only one or two individuals of each of the other species.

The diet of male and female cats was similar. In 1972 the proportions of adult male and female cats containing remains of birds, or containing rats did not differ significantly (χ^2 with Yates correction = 0.437 and 0.103 respectively). Of the five cats containing remains of Norway rats, four were males and the sex of the other was not recorded. Because only three juvenile cats were collected in 1972, the diet of adults and juveniles could not be compared.

Discussion

The cats on Raoul Island prey almost entirely on rats and birds, as they do on other oceanic islands where these are the main vertebrate prey available. On islands where rabbits and rats are present rabbits are the main prey of cats and few rats are taken (Jones, 1977; Fitzgerald, 1988). On most of the islands where the diet of cats has been studied, and where rats were important prey, just one species of rat was present; kiore on Little Barrier (Marshall, 1966), ship rats (*Rattus rattus*) on Santa Cruz and Isabela Islands, Galapagos Archipelago (Konecny, 1983, 1987), Lord Howe Island (Miller and Mullette, 1985) and Aldabra Atoll (Seabrook, 1990), and Norway rats on Campbell Island (Dilks, 1979) and Amsterdam Island (Furet, 1989). Only on two islands (Raoul and Stewart) were two or more species of rat present, providing an opportunity to compare their frequency in the diet of cats with their availability. On Stewart Island, three species - Norway rats, ship rats and kiore - were present, but remains of rats in the scats could not be identified to species (Karl and Best, 1982). On Raoul Island, predation on rats falls very largely on kiore, although Norway rats appear to be more common than kiore.

Snap-trapping for rats has been carried out at various times on Raoul Island, with Norway rats always predominating in the catch. In 1966/67, 10 Norway rats and nine kiore were trapped (Merton, 1970, p. 151), not 11 Norway rats and eight kiore as given by Merton (1968, p. 13 - D.V. Merton, *pers. comm.*). During October and November 1974 J.C. Smuts-Kennedy trapped 14 Norway rats and one kiore (K.A. Wodzicki, *in litt.* 1975). In November 1980 BJK trapped seven Norway rats and one kiore near the sooty tern colony at Denham Bay and in March 1984 John Craig trapped 20 Norway rats and six kiore in forest and five Norway rats and two kiore in grassland (J.L. Craig, *pers. comm.*). In 1972 rats that were caught in gin traps set for cats were preserved and deposited in the rodent collection at

Ecology Division (currently DSIR Land Resources). They comprise 38 Norway rats and only two kiore. In total, only 18% of the rats caught have been kiore.

Norway rats are much larger than kiore; adult Norway rats weigh about 150-300 g and adult kiore about 50-100 g. Also, as Norway rats reach adult size they develop aggressive behaviour towards predators, so cats mainly catch young rats (Leyhausen, 1979). Field observations show that most of the Norway rats caught by cats are young. Childs (1986) found in an urban environment that cats prey on young rats weighing less than 200 g (mostly below 100 g) and do not kill adults. Cats hunting Norway rats at a farm refuse tip caught young rats (Brodie, 1988), and cats on Amsterdam Island preyed especially on young rats of less than 100 g (Furet, 1989). The larger size and aggressiveness of Norway rats may help to explain the predominance of kiore, rather than the more common Norway rats, in the diet of cats on Raoul Island.

Most of the birds eaten by cats were passerines and those eaten most frequently (tui, starling and blackbird/thrush) are among the most common passerines on the island (Merton and Veitch, 1986).

Although few seabirds are now recorded in the diet - only one Kermadec little shearwater and two sooty terns in the cats - seabirds probably formed a large part of the cats' diet when cats first arrived on Raoul Island. The breeding populations of petrels on Raoul Island have been greatly reduced since then. In 1908 wedge-tailed shearwaters (*Puffinus pacificus pacificus*), white-naped petrel (*Pterodroma cervicalis cervicalis*), Kermadec petrel (*P. neglecta*), and black-winged petrel (*P. nigripennis*) were abundant (Iredale, 1910, 1912, 1914; Merton, 1970). By 1966 wedge-tailed shearwaters were reduced to small colonies on the headlands and cliffs and the breeding colonies of other petrels were virtually eliminated. Cat-eaten remains of many wedge-tailed shearwaters, black-winged petrels, sooty terns and grey ternlets (*Procelsterna cerulea albivittata*), a few Kermadec little shearwaters and one white-capped noddy (*Anous tenuirostris minutus*) were found in 1966 (Merton, 1970). Cat-eaten remains of Kermadec little shearwaters were found in 1966, and they were recorded in cats in 1972 but they have never been a common breeding species on Raoul Island (Merton, 1970). Cats are also recorded preying on white terns (*Gygis alba*, Bell, 1912). Although the diet of cats, averaged over the whole island, now includes few seabirds a few cats living near the remaining breeding colonies of seabirds may still feed largely on seabirds.

The scarcity of seabirds in the diet of cats on Raoul now contrasts with islands where cats (without rats) have been present for a short time. On Howland and Jarvis Islands in the tropical Pacific, where cats had been present for 13 and 45 years respectively, seabirds, especially sooty terns, were important prey of cats

(Kirkpatrick and Rauzon, 1986). On Herekopare Island in Foveaux Strait, fairy prions (*Pachyptila turtur*), broad-billed prions (*P. vittata*) and diving petrels (*Pelecanoides urinatrix*) had been the main food of cats but after 45 years only fairy prions remained (Fitzgerald and Veitch, 1985). On Marion Island, in the south Indian Ocean, where at least seven species of petrels are recorded eaten (van Aarde, 1980; van Rensburg, 1985), the frequency of petrels in the gut contents has decreased from 97% in 1975 to 60% in 1988/89, reflecting the decline in the size of the petrel populations (Bloomer and Bester, 1990).

One management option for Raoul Island is to eradicate cats but this may bring little benefit to bird populations. Norway rats are important predators on some islands (Atkinson, 1985), and Taylor (1979) thought that they "could be the most damaging predator of sooty terns at Raoul". On Campbell Island, where Norway rats are the only mammalian prey, cats have apparently always been scarce although Norway rats are abundant and form most of their diet (Dilks, 1979). Perhaps few cats survive the months when the rats are not breeding; young rats are not available and other food is scarce (Fitzgerald 1988). Norway rats have been present on Campbell Island since before 1868 but cats became established probably only after 1916 and it is possible that Norway rats, rather than cats, were responsible for much of the destruction of the seabird colonies and the restriction of the Campbell Island teal (*Anas aucklandica nesiotis*) and the pipit (*Anthus novaeseelandiae*) to nearby, rat and cat-free Dent Island (Dilks, 1979). Similarly, on those parts of South Georgia where Norway rats are established South Georgian pintails (*Anas georgicus*) and Antarctic pipits (*Anthus antarcticus*) are missing (Pye and Bonner, 1980). Domestic cats were present on South Georgia but have probably died out (Bonner, 1984). Many other examples of populations of birds, especially seabirds, being reduced on islands where Norway rats have become established are given by Atkinson (1985).

If cats were eradicated the Norway rat population on Raoul Island is likely to remain at least as high as it is now, and the rats on their own might kill sufficient sooty terns in the colonies at Denham Bay and on the south coast of Hutchison Bluff to reduce the size of the colonies further. The scattered petrel colonies would probably also continue to decline. Other seabirds, especially the petrels that once bred in vast colonies, are unlikely to be able to re-establish themselves in the presence of Norway rats. On the positive side, if cats were eradicated the few remaining white terns, which nest in pohutukawa trees (Merton, 1970), might increase in numbers and parakeets from the adjacent Herald Islets might recolonise Raoul. Bird nests preyed on by Norway rats are mainly those in burrows, on the ground surface or less than three metres above ground (Atkinson, 1985); on North Meyer Island parakeets nest

in holes in banks or trees close to the ground (Edgar *et al.*, 1965; Merton, 1970) but on Raoul Island the pohutukawa forest may provide sufficient nest sites above this height for parakeets to be able to re-establish themselves.

Thus, eradicating cats may produce little change in bird populations, except perhaps white terns, parakeets and some of the passerines. Unless it is possible to eradicate Norway rats as well as cats from Raoul Island the effort and expense involved in a cat eradication programme might be better spent on other conservation projects that are more assured of a positive outcome.

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