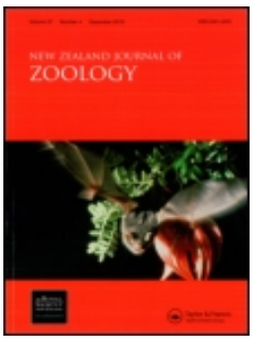

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The cats of Herekopare Island, New Zealand; their history, ecology and affects on birdlife

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Abstract House cats (*Felis catus)* were introduced to Herekopare Island, a mammal-free island of about 28 ha near Stewart Island, in about 1925. In winter 1970, the total population of 33 cats (20 males, 13 females) — a density of 1.2 cats/ha — was killed, mainly by trapping. Examination of stomach contents and scats showed that the cats fed mainly on petrels, supplemented by land birds and insects. The bird life of Herekopare Island was studied by H. Guthrie-Smith in 1911, L. E. Richdale in the early 1940s, and by New Zealand Wildlife Service staff in 1968 and 1970. Their accounts indicate that a vast breeding population of diving petrels and thousands of broad-billed prions were probably exterminated by the cats, though fairy prions and sooty shearwaters persisted. Among land birds, the yellow-crowned parakeet, robin, fernbird, brown creeper, Stewart Island snipe, and banded rail were exterminated. Two other species, the red-crowned parakeet and tomtit, probably disappeared but subsequently recolonised the island. Although cats had the greatest influence on the bird life over this period, wekas, which were present for some years, together with changes in the vegetation, may have affected some bird populations.

Keywords *Felis catus;* feral cat; predation; food habits; eradication; Stewart Island; petrels; broad-billed prion; fairy prion; diving petrel

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INTRODUCTION

House cats (*Felis catus*) have been introduced to, and become feral on, at least 12 islands in the New Zealand region (Veitch 1985). These islands previously lacked carnivores and the cats have devastated the birdlife (Merton 1978; Veitch 1985), though often their impact is poorly documented. Although feral cats are primarily predators of small mammals, and birds usually form only a small part of their diet, on islands birds make up a large part of their diet (Fitzgerald & Karl 1979).

On most islands where cats have been introduced some mammalian prey is available. For example, on Little Barrier Island cats ate mainly *Rattus exulans* in winter and nesting seabirds in summer (Marshall 1961); on Macquarie Island rabbits were the main food but petrels and prions were also important (Jones 1977). An interesting exception is Herekopare Island, off Stewart Island, where there are no other mammals besides cats, but large populations of sea and land birds. Cats were introduced relatively recently and changes in the bird populations are better documented than for many other islands.

A decision to exterminate the cats on Herekopare Island was made in 1970 by the Wildlife Service, Department of Internal Affairs. A wildlife team visited Herekopare Island from 6 June to 9 July 1970, and eradicated the cat population. This paper reports on the history of cats on the island, the characteristics of the cat population in 1970, the changes in the bird populations, and on the role of cats in these changes.

HEREKOPARE ISLAND

Herekopare Island (46°52′S, 168°14′E) lies 8 km eastnortheast of Halfmoon Bay, Stewart Island (Fig. 1). Its nearest neighbour, Jacky Lee Island, lies 1.6 km NNW. Herekopare Island has an area of 28 ha, rises to about 90 m above sea level, and is roughly flat on top. Rainfall at Oban, Stewart Island, 8 km WSW of Herekopare Island averages 1467 mm/year distributed fairly evenly throughout the year; average maximum and minimum temperatures at Tiwai Point, Bluff, 30 km NNE of Herekopare Island are 14.1°C and 7.0°C respectively (New Zealand Meteorological Service 1983).

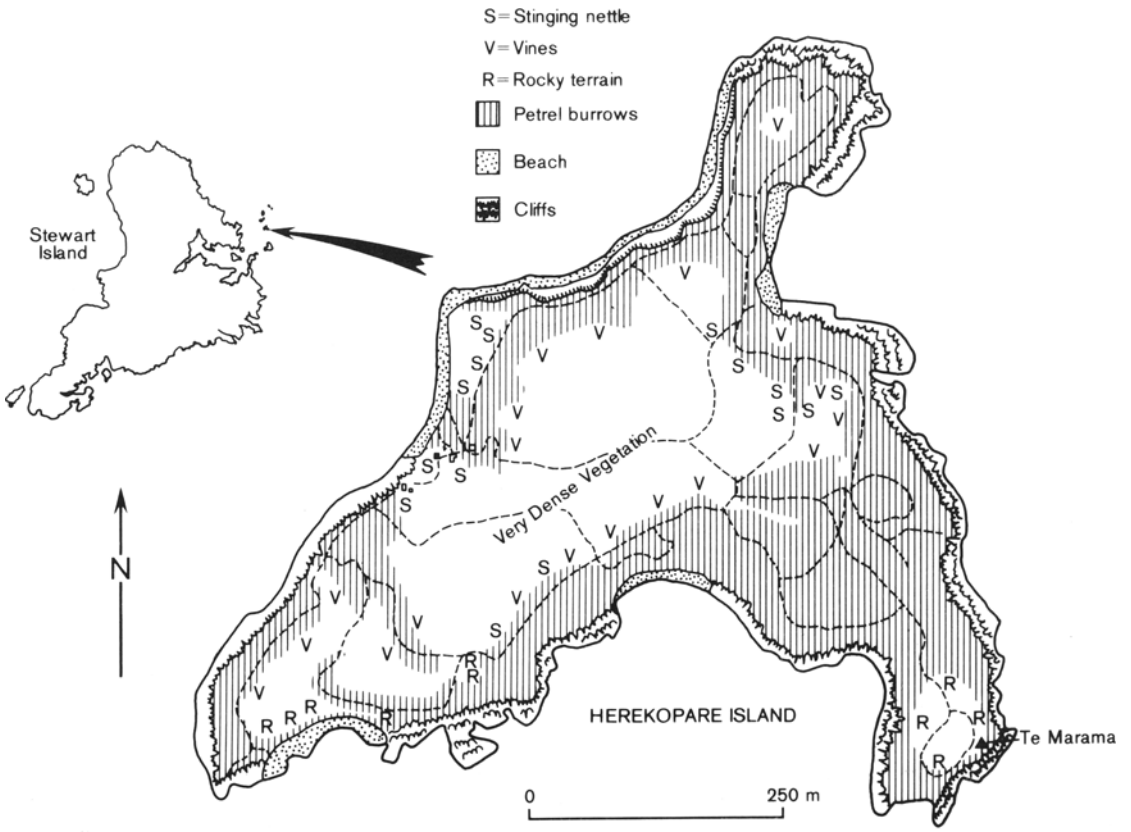

Fig. 1 Herekopare Island and the distribution of petrel burrows and vegetation (mapped by J. J. Andrew).

Most of the island is covered in scrub, dense in places, with some light bush in the centre and more sheltered parts. The scrub is characterised by the tree daisies, *Senecio stewartiae, S. reinoldii, Olearia angustifolia* and *O. lyallii* (Johnson 1976). The bush includes *Griselinia lucida, G. littoralis, Fuchsia excorticata, Aristotelia serrata* and *Pennantia corymbosa* (J. M. Neilson pers. comm.).

In 1911 the taller vegetation was mostly *S. stewartiae,* an open-branched shrub 2–3.5 m tall, and *Hebe elliptica* (Poppelwell 1915). Guthrie-Smith (1914: 14) noted that *Senecio* did not seem to be replacing itself; he found no young plants although *Olearia angustifolia* seedlings were abundant. By 1970 many of the *S. stewartiae* had died although their skeletons remained. Tree nettle (*Urtica ferox*) was dominant in some places, possibly having grown up in the light gaps created where *S. stewartiae* had died. Fires have burnt some parts of the island, and these areas are now covered in grass and fern.

The island has no permanent residents. It is owned by the Crown; descendants of the original Maori owners have the right to take muttonbirds (Wilson 1979), but in recent years only three families have done so. Accounts of the species of birds recorded on Herekopare Island, and their scientific names, are given in the Appendix.

METHODS

Information on the history of cats and birds on the island was obtained from the literature, and observations on birds were made by CRV. Cats were caught by gin traps and by hunting with dogs.

Gin traps were set on the ground close to a tree or fallen log, camouflaged with a light covering of soil and leaf litter, and baited with fish. Baits were replaced frequently and occasionally cod liver oil was added (see Veitch 1985). Traps were set at 25–75 m spacing, and covered all parts of the island. Dogs, experienced in hunting for cats, were kept on the island throughout the programme and any cat cornered by a dog was shot.

Cats were autopsied and details recorded of sex, weight, measurements, coat colour, reproductive condition, stomach contents, and general body

condition (fat, medium, thin). A cat was described as 'fat' if it had some fat under the skin with much fat around the stomach and fat covering the kidneys, as 'medium' if it had less stomach fat and the kidneys were partly exposed, and as 'thin' if it had virtually no fat around the stomach or kidneys. Skulls were saved; animals were classified as juveniles if milk teeth were present and as subadults if the skull was juvenile in shape and lacked sagittal and occipital crests, but had permanent teeth.

Many cat scats were collected and combined into one sample. This material was washed in water, and all bones and chitinous material separated. Species of birds were identified by comparing the bones from scats with reference skeletons, and the number of individuals was counted from the most common of several distinctive bones (tarsus, tibia, femur, humerus, mandible and quadrate). Bones from young birds were recognised by their dull and rather porous appearance. Wetas (Orthoptera) were counted from the mandibles.

RESULTS

History of cats on the island

Cats were not present on Herekopare Island in 1911 when Guthrie-Smith observed the rich bird life (Guthrie-Smith 1914). Richdale [1943] stated that cats were introduced to the island in about 1931, but Edgar Stead and R. A. Wilson found very few birds on Herekopare Island in December 1932 and considered that cats must have been introduced much earlier than 1931 (Wilson 1959). Mr P. R. (Buddy) Willa, who had muttonbirding rights on Herekopare Island, reported (pers. comm.) that cats were accidentally introduced to the island about 1926; C. M. Miskelly (pers. comm.) was told more recently by Mr and Mrs Willa that cats were introduced to Herekopare Island in 1924.

In the early 1940s L. E. Richdale and the Southland and Otago branches of the Royal Society made strong representations to the Minister of Internal Affairs to have the cats on Herekopare Island exterminated (Otago Branch of the Royal Society of New Zealand 1943; Southland Branch of the Royal Society of New Zealand 1943, 1944, 1945). These branches of the Royal Society opened a subscription list for funds to be used to destroy cats. In their Annual Reports for 1942 they stated that "the campaign is now being pushed vigorously" and that "to date a number of cats have been destroyed". A year later "another small amount of work has been done ... the total number of cats destroyed to date is 88". The Southland Branch (1945) reported that "during the year the work of bird protection was carried on, on Herekopare Island, and after visiting the island at Christmas time in company with Mr William Denham, Mr Richdale gave it as his opinion that the cats would disappear this coming winter". Efforts then appear to have been relaxed.

During this period Richdale killed cats whenever he visited the island. On a 10-day visit in May 1942 he killed five (Southland Times, 23 May 1942: 4), in May 1943 another five (Richdale [1943]), and with Mr Denham in December 1943 and January 1944 he killed 10 (Richdale, letter to the Southland Times, 17 January 1944: 3). Cats were also killed in the early 1940s by Mr F. Woodrow, an Internal Affairs officer. More recently cats have been killed by muttonbirders. Mr T. Wast and Mr P. Whipp report that they killed 69 cats in 1965, 19 in 1966, 16 in 1967, 30 in 1968, 17 in 1969, and 6 in 1970.

The cats in 1970

The first trap was set on the island on 6 June 1970 and 111 more in the next 6 days; another 6 were set on 21 June, and all 118 traps were then operated until 27 June (Fig. 2). A few traps were again set from 1 to 6 July.

Thirty-three cats were collected from the island (Fig. 2). Thirty cats were trapped and one was shot in the first 4 days of hunting. An adult female evaded the traps and dogs for another 12 days before it was cornered by a dog and shot on 23 June. An adult male also evaded the traps; it was chased by a dog on 24 and 25 June, a fresh, cat-eaten fairy prion was found on 1 July, and a fresh cat scat was found on 3 July. The cat was found dead on 6 July, and had been dead for about 3 or 4 days. It was thought to have died from the effects of an abcess, extending from the right upper third premolar into the eye socket. The dogs searched the island thoroughly until 9 July but found no further sign of cats. Twelve of the 13 adult males were caught in the first 2 days, whereas only half the 8 adult females were caught then (Fig. 2).

The remains of another six cats were also found; three juveniles had probably been dead for less than a month and two adults and a juvenile for much longer. Muttonbirders report that in autumn 1970 they killed six cats (T. Wast & P. Whipp pers. comm.). The 33 cats alive at the beginning of the extermination programme represent a density of 1.18 cats/ha and the 21 adults represent 0.75 adults/ha.

The sex ratio was 20 males and 13 females — 21 adults (13♂, 8♀), 2 subadults (1♂, 1♀) and 10 juveniles (6♂, 4 ♀). The sex ratio (61%♂) does not differ significantly from 1 : 1 and the sex ratio of adults (62%♂) and juveniles (58%♂) is similar, but the samples are small.

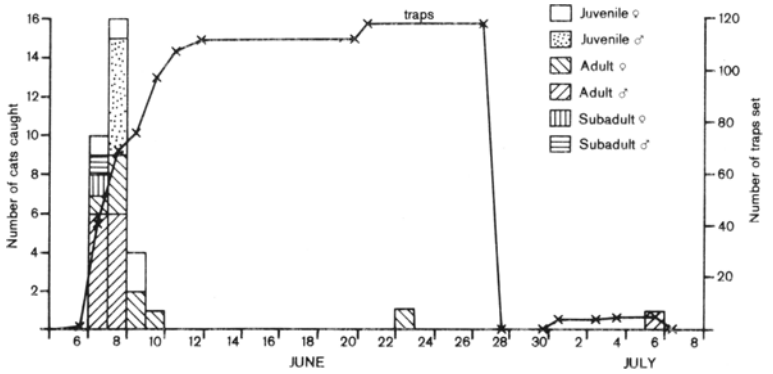

Fig. 2 Daily trapping effort and the sex and age of cats caught.

Table 1 Body weights of the cats n = no. of cats.

	Av. weight (kg)	SD	Range	n
Adult males	3.36	0.23	2.8–3.6	12
Adult females	2.75	0.30	2.3–3.3	8
Subadult male	2.1			1
Subadult female	1.6			1
Juvenile males	1.53		1.2–2.0	6
Juvenile females	1.45		1.3–1.6	4

Adult males (mean weight 3.36 kg, Table 1) were significantly heavier than adult females (mean 2.75 kg) ($t_{d.f.18} = 5.152$, $P < 0.001$). The heaviest juveniles (i.e., with milk teeth) were two males of 2.0 kg and a female of 1.6 kg. The two subadult cats were of similar weight to the heaviest of the juveniles and differed from them chiefly in having full permanent teeth. The subadults were both 0.7 kg lighter than the lightest of the adults of the same sex.

At autopsy, the condition of the cats was rated according to the amount of internal fat. Six males were described as fat, 13 as medium, and none as thin (1 not recorded), while 7 females were described as fat, 5 as medium and none as thin (1 not recorded). The juveniles were all in good condition with 7 recorded as fat, and 4 as medium (1 not recorded).

None of the adult females was pregnant or lactating; one had large nipples but all others had small nipples. A ratio of 12 juveniles and subadults to 8 adult females represents 1.5 young per female surviving to an age where the young are becoming independent of the female.

All of the adults and most of the juveniles were black and short-haired but three of the smallest juveniles were long-haired and two of them had hair which was soft and very dark grey. Twenty-five (76%) had some white hair, generally restricted to the paws and underparts of the body. However, the white on one male extended up its sides and across the shoulders.

The stomach contents varied considerably in quantity, and we did not try to estimate the amount of food present; foods are therefore given by frequency only (Table 2). One stomach was empty and another contained only fish bait. Prions were the most frequent food, present in 87% of the stomachs. They were not identified to species but most were probably fairy prions, as broad-billed prions were rare on the island. The only sooty shearwater material found was half of a decayed shearwater leg, presumably eaten as carrion. Similarly, the eggshell fragments in three stomachs were probably from addled eggs or egg fragments, that had persisted from the breeding season in November–January. The only land bird recorded in the stomachs was a silvereye, which is the most common species on the island in June and July. Wetas (Orthoptera) were recorded in 14 stomachs, of which 7 contained remains of more than 10, and 2 contained more than 100 wetas. When taken in such numbers these insects can make an important contribution to the diet of cats. "Rock shrimps" recorded in one cat were small crustaceans found among rocks in the intertidal zone at night.

Six of the stomachs contained from one to four large nematodes (average 2.3). No other parasites were noted.

Fairy prions were by far the most frequent birds found in the scats, with 20 identified (Table 3). Nearly all were adults, the only bone from a young bird being one metatarsus, almost certainly from a fairy prion. Half as many land birds were found as prions and shearwaters, and as most land birds were considerably smaller than petrels (half of the land birds recorded were silvereyes), they contributed even less to the cats' diet. Bones from at least two birds could not be identified, but one might have been a starling.

The foot of one skink (*Leiolopisma* sp.) was found in the droppings. Remains of wetas were frequently found, and mandibles of at least 56 were counted.

Table 2 Stomach contents of cats.

	No. stomachs
Empty or fish bait only	2
Fish bait	3
Number with contents	30
Sooty shearwater	1
Fairy prion	26
Broad-billed prion	
Silvereye	1
Eggshell	3
Weta	14
"Rock shrimp"	1
Nematodes	6

Table 3 Prey identified from cat scats.

		Number
Birds		
	Broad-billed prion	1
	Fairy prion	20*
	Sooty shearwater	3
	Red-crowned parakeet	1
	Song thrush	1
	Silvereye	6
	Finch (Yellowhammer?)	1
	Unidentified	> 2
Reptiles		
	Lizard (*Leiolopisma sp.*)	1
Insects		
	Weta (Orthoptera)	56

*Includes 1 juvenile metatarsus.

Changes in bird populations

The bird populations on Herekopare Island have been observed intermittently over the past 60 years. The island was visited in 1911 by Guthrie-Smith (1914), in 1932 by Edgar Stead and R. A. Wilson (Wilson 1959), and in the early 1940s by Richdale during studies of petrels on Whero Island (Richdale [1943], [1949], 1942, 1943, 1944a, b, 1945a, b, 1963, 1965a, b). It was also visited to control the cats in the early 1940s by B. A. Vercoe and F. Woodrow of the Department of Internal Affairs, and in 1968 and 1970 by members of the New Zealand Wildlife Service. Species accounts for the birds are given in the Appendix. Guthrie-Smith (1914) made three visits to Herekopare Island in 1911, recording more than 20 species and photographing several of them.

In the early 1940s Richdale reported that cats had exterminated several bird species from Herekopare Island since Guthrie-Smith's visits. "To my knowledge six of the species then present are now, owing to the cats, extinct" (Richdale 1942: 85), "cats inadvertently introduced to the island, have already caused the extermination of six species of birds" (Richdale 1943: 27) and "six species, as residents, have disappeared entirely" Richdale ([1943]: 40). The Otago Daily Times of 15 October 1941 (p.7), reporting an address by Richdale to the Otago Branch of the Royal Society of New Zealand, listed five species that had been exterminated: the parakeet, robin, tomtit, fernbird, and korure (mottled petrel). The Southland Times of 23 May 1942 (p.4), reporting an interview with Richdale, gave a slightly different list: red-crowned and yellow-crowned parakeets, robin, tomtit, and fernbird.

Of these species Guthrie-Smith (1914) observed yellow-crowned parakeets, fernbirds, robins, and tomtits on Herekopare Island in 1911. Neither he nor subsequent visitors mentioned the mottled petrel, so it should probably be deleted from the list of species. Two other species recorded by Guthrie-Smith, and which Richdale thought had been exterminated by cats, were present in 1970. The red-crowned parakeet was recorded by B. A. Vercoe in 1943 and was present in 1970. Tomtits were not recorded in the 1940s but had recolonised the island by 1970, despite the presence of cats. Guthrie-Smith (1914) also recorded brown creepers; they were seen by B. A. Vercoe in 1943 but were not present in 1970 and were probably eliminated by cats. In addition, banded rails and Stewart Island snipe were reported by muttonbirders and were last seen on the island about 1924. Thus, six species of land birds (yellow-crowned parakeet, fernbird, robin, brown creeper, banded rail and snipe) had disappeared from the island by 1970.

The changes in the seabird populations of the island are more difficult to assess because the birds visit the island only to breed, and the population may be supplemented by surplus birds from nearby islands. Guthrie-Smith (1914) described broad-billed and fairy prions as present in thousands and diving petrels "perhaps in millions" (see Appendix for more detailed descriptions of the seabird populations). Guthrie-Smith (1914: 27) considered that diving petrels formed the majority of the seabirds nesting on Herekopare Island. In the early 1940s Richdale (1943, 1944a, b) found "a great many diving petrels", "some hundreds" of broad-billed prions, and fairy prions were "present, though sparsely". By 1968–70 diving petrels were virtually gone. They were not seen by J. S. Adams and J. W. Cheyne in December 1968 or by CRV in June–July 1970, and none was found in cat scats though

muttonbirders reported that they were still present. Similarly, broad-billed prions were extremely rare; Adams and Cheyne in December 1968 saw none, and bones of only one bird were found in cat scats in 1970.

These reports indicate that the vast population of diving petrels, and the smaller but substantial population of broad-billed prions, had been virtually eliminated. Changes in the numbers of fairy prions and sooty shearwaters are not as clear. Fairy prions were described by Guthrie-Smith (1914) as present in thousands, and by Richdale (1944b) as sparse, but in 1968 and 1970 they were present in large numbers and were the main food of the cats. This suggests that the numbers of fairy prions might have increased since the early 1940s, but the subjective descriptions given make it difficult to be certain. The numbers of sooty shearwaters have probably changed less than those of the smaller species. Guthrie-Smith (1914) put the population at a few thousand, and Richdale's comments (1945a: 49) on the few young taken by muttonbirders suggest a population of a few hundred in the 1940s. Numerous cat-eaten shearwaters were found in 1970.

DISCUSSION

On most islands where cats have been studied, rodents or rabbits are present, and these are eaten, together with nesting seabirds and some land birds (Marshall 1961; Heidemann 1973; Derenne 1976; Derenne & Mougin 1976; Jones 1977; Dilks 1979; Van Aarde 1980). On Herekopare Island there were no mammalian prey and the cats relied mainly on the petrels which were abundant during the breeding season from spring to autumn and present in small numbers in winter. This shows cats, although usually predators of small mammals, can thrive when released on to islands with dense breeding populations of birds.

Although there were 33 cats on the island in winter 1970, reports indicate that cats were sometimes more abundant in the past. Such large numbers were possible only because the cats were feeding mainly on seabirds that came to the island to breed. Comparable or higher densities of cats are found in cities and suburbs where they scavenge on garbage or are fed by people (Obrtel & Holisova 1980). Despite the high density of cats on Herekopare Island, they were in good condition, even in mid winter when food is probably scarcest. The population also seems to have been quite productive, with 1.5 young present per adult female. These young weighed on average about 1.5 kg, and Fitzgerald & Karl (1979) found that young cats reaching this weight were likely to survive to become adult members of the population.

The observations on Herekopare Island suggest that some bird groups are more likely to suffer than others when cats are introduced to an island. Ground-feeding species of birds are particularly vulnerable; of the six species that disappeared, only the brown creeper feeds almost entirely above ground in the foliage and on branches and trunks (Gill 1980). In contrast, of six native species of land birds present in 1970 (red-crowned parakeet, grey warbler, fantail, tomtit, bellbird, and tui), only the red-crowned parakeet and tomtit feed much on the ground. These two had apparently disappeared by the 1940s, but subsequently recolonised the island. Ground-feeding birds also formed the majority of birds eaten by cats in a mainland forest (Fitzgerald & Karl 1979) and on Stewart Island (Karl & Best 1982).

On Socorro Island, off the Mexican coast, feral cats have exterminated the endemic dove and mockingbird, and reduced the numbers of the towhee (all ground-feeders), although tree-dwelling species remain common (Jehl & Parkes 1983).

Nesting petrels also suffered very heavy predation on Herekopare Island and the susceptibility of the different species was probably influenced by their size and the timing of breeding. Diving petrels are the smallest of the species with an average weight of 121 g, fairy prions are 132 g, broad-billed prions 196 g, and sooty shearwaters are the largest at 787 g. All four species nest in burrows, and their breeding seasons are staggered somewhat (Richdale 1943, 1944a, b, 1963, 1965a, b). Broad-billed prions lay earliest, from late August to mid September, followed by diving petrels, fairy prions and sooty shearwaters, respectively (Fig. 3).

Features of the breeding biology of diving petrels (Richdale 1943, 1945b, 1965a) also make it the species most vulnerable to predation. During incubation the birds change nightly whereas fairy prions change every 6–7 days (Richdale 1944b) and sooty shearwaters every 1–16 days, probably on average about 7 days (Richdale 1963). The chicks of diving petrels are fed by both parents each night whereas broad-billed and fairy prion chicks are not fed on about 15% of the nights (Richdale 1944a, b) and sooty shearwater chicks are fed about once every three nights (Richdale 1963). The nestling period of the diving petrel is also longer than that of broad-billed and fairy prions, so the birds are at risk for longer. These factors may help explain why the very large population of diving petrels was eliminated, yet fairy prions persisted.

On Hog Island in the Crozet Archipelago, Indian Ocean, cats have been present since the second half of the 19th century and have eliminated, or virtually eliminated, all the small surface-nesting seabirds, and both the large and small burrow-nesting species. Only the surface-nesting species that are

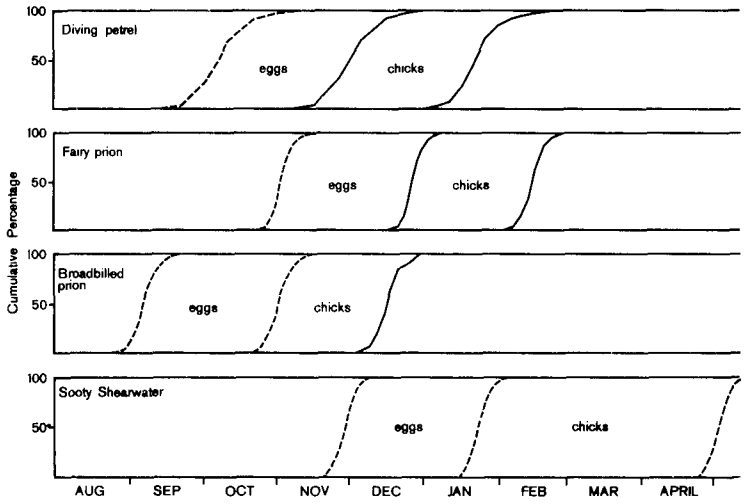

Fig. 3 Breeding seasons of diving petrels, fairy and broad-billed prions and sooty shearwaters (based on Richdale 1944a, b, 1945a, b, 1963, 1965a).

too large for cats to attack, and the medium-sized burrow-nesting species that dig deep, narrow burrows, are still common (Derenne & Mougin 1976).

Petrels also return to Herekopare Island outside the breeding season. Most prions have left the island by the end of February but in May 1942 and 1943 broad-billed prions were present again and the remains of many were found, although no fairy prions were recorded (Richdale 1945, 1965b). In June–July 1970 some fairy prions were present, fresh cat-eaten birds were seen and they formed the bulk of the stomach contents (Table 2). The last of the sooty shearwater chicks leave the island in the first half of May. Diving petrels and prions return to the island and clean out burrows some time before they lay eggs (Richdale (1965a, b) reports that they had returned to Herekopare Island by late August). There is therefore little time when some petrels are not available to the cats, though their numbers might vary considerably and food is probably scarcest in the winter months.

Diving petrels and broad-billed prions breed considerably earlier than the other species so when they were eliminated the period when food was scarce could have been lengthened by up to two months.

Our results show some of the effects of cats on the birdlife of Herekopare Island, but during the long intervals between surveys of the birdlife, some changes may have passed unnoticed. In the presence of cats some species that were previously breeding residents may have become visitors or occasional breeders from nearby islands. Richdale (1942) reported that red-crowned parakeets were daily visitors to Whero Island, and in 1970 pigeons were seen flying from Stewart Island to Herekopare and other islands.

The effects of cats on the bird populations of Herekopare Island may be confused to some extent by other factors operating at times since 1911. Wekas were present on the island for some years from the 1920s to at least the mid 1940s, though the records are rather contradictory (see Appendix). At times wekas must have been abundant, because muttonbirders report that 300 were killed in one season. Wilson (1959) considered that wekas were just as destructive as cats on the muttonbird islands. He and Edgar Stead visited Jacky Lee Island in December 1932; diving petrels were fairly numerous and many were found dead, partly eaten by wekas. When they returned in December 1940 they found that wekas had multiplied greatly, diving petrels were gone, and prions were reduced to "a mere handful" compared to what they saw previously. Muttonbirds were taken on Jacky Lee Island until 1929 (Wilson 1959) but in 1964 when CRV visited the island no sooty shearwaters were to be found. Similarly, on Codfish Island Blackburn (1968) found the fresh remains of many mottled petrels that had been killed and stripped clean by wekas. He suggested that wekas seriously threatened the survival of mottled petrels on the island and had virtually eliminated Cook's petrel and diving petrels. He also pointed out that banded rails are common on islands without wekas but absent from islands with wekas. On Macquarie Island several species of petrel have decreased dramatically or become extinct under the combined predation of wekas and cats (Brothers 1984).

Changes in the vegetation of Herekopare Island between 1911 and 1970 may also have affected the bird populations. Most petrel burrows were found under *Senecio stewartiae* and *Hebe elliptica,* and they were absent from areas of stinging nettle or

very dense vegetation. The mortality of *S. stewartiae* and the increase in the area of nettle since 1911 may have made the island less suitable for petrels, and compounded the effects of cats.

In assessing the effects of cats on some island faunas the annual predation rate on the seabird populations has been estimated (Derenne & Mougin 1976; Jones 1977; Van Aarde 1980). We have not attempted this because we do not have sufficiently precise data on the cats and their prey. Just as convincing though are the observations that the populations of landbirds or nesting seabirds are reduced or exterminated on islands after cats have been introduced, and that far fewer species nest on islands with cats than on nearby islands without cats.

On Little Barrier Island, northern New Zealand, the saddleback (*Philesturnus carunculatus*) disappeared soon after cats were introduced in the 1870s (Turbott 1961; Veitch 1985). Grey-faced petrels (*Pterodroma macroptera gouldii*) were suffering serious predation by cats in the 1940s (Turbott 1961) and have ceased breeding there since 1963 (CRV, pers. obs.); black petrels (*Procellaria parkinsonii*) also suffered heavy predation in the early 1970s, and the population was declining (Imber 1975). On Hog Island in the Crozet Archipelago, cats have been present for about 100 years and only 17–19 species of birds nest there now compared with 27–35 species on nearby East Island (Derenne & Mougin 1976). On Marion Island, diving and storm petrels have been greatly reduced in numbers since cats were introduced, but remain common on the neighbouring, cat-free Prince Edward Island (Van Aarde 1980). On Raoul Island in the Kermadecs, and on Ascension Island in the Atlantic Ocean, most of the breeding seabirds have been eliminated by cats though they still breed on small offshore islands. Only the sooty or wideawake tern (*Sterna fuscata*) still breed in considerable numbers (Stonehouse 1962; Merton 1970) and on Raoul Island even these may be threatened (Taylor 1979). Stonehouse (1962) suggested that the breeding colonies of wideawake terns can persist on Ascension Island because the terns are completely absent for 3 out of the 9–10 months of each breeding cycle and many cats die during this lean period.

Cats have been introduced to more than a dozen biologically important islands around New Zealand and have subsequently been eradicated from about half of them, including Stephens (108 ha), Cuvier (194 ha), Kapiti (2023 ha) and Little Barrier (2817 ha) Islands (Merton 1978, Veitch, 1985). Removing cats is a conservation measure that is relatively easy on islands as small as Herekopare and Cuvier but it has also been achieved on two much larger, rugged islands of biological significance in the New Zealand region. Cats were eradicated from Kapiti Island by the caretaker by 1934 and recently teams have successfully removed all cats from Little Barrier Island (Veitch, 1985). This shows that given sufficient resources it is possible to eradicate cats from quite large islands and attempts can then be made to reintroduce species that the cats had exterminated.

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APPENDIX

Birds of Herekopare Island

In June–July 1970 three mist-nets were operated during most of the visit and 88 birds were caught, banded, and released. Notes were also kept of species seen or heard. These are compared with the unpublished records of J. S. Adams and J. W. Cheyne (New Zealand Wildlife Service) in December 1968 and with earlier published records.

The numbers of nesting seabirds could not be assessed during winter, outside the breeding season, but the distribution of petrel burrows on the island was mapped by J. J. Andrew (Fig. 1). Burrows were absent from most of the central part of the island under very dense vegetation.

Species List

Yellow-eyed Penguin (*Megadyptes antipodes*). Recorded nesting in December 1968 by Adams and Cheyne. Not recorded by earlier observers or in winter 1970.

Southern Blue Penguin (*Eudyptula minor*). Recorded nesting by Adams and Cheyne in December 1968 but not mentioned by earlier visitors. Moderate numbers came ashore at night in 1970. The dog retrieved more than 20 penguins while hunting for cats.

Mottled Petrel (*Pterodroma inexpectata*). L. E. Richdale (quoted by the Otago Daily Times, 15 October 1941: 7) reported that the mottled petrel had become extinct on Herekopare Island. Guthrie-Smith (1914) did not record it and it has not been reported by subsequent visitors.

Broad-billed Prion or Parara (*Pachyptila vittata*). Guthrie-Smith (1914) in October 1911 recorded broad-billed prions arriving at dusk in thousands. Richdale reported their numbers in 1941–43 as follows. In late August 1941 there were broad-billed prions about and "the remains of birds destroyed by cats were littered all over the island". In late August 1942 "some hundreds of birds were present" but "bird remains left by cats were very much fewer, indicating that these pests, during the preceding twelve months had made further inroads into the population" (Richdale 1944: 210). In May 1942 broad-billed prions were making sporadic visits to the breeding areas and were recorded in some hundreds, though the young had left by the end of December (Richdale 1944: 209). In May 1943 remains of many broad-billed prions killed by cats were found (Richdale 1945: 42).

In December 1968 Adams and Cheyne did not record any birds. Only old cat-eaten remains were found in the winter of 1970 but the bones of one bird were found in cat droppings. Muttonbirders reported that they saw one bird on the island during the muttonbirding season in April–May 1970.

Fairy Prion or Titi-Wainui (*P. turtur*). Guthrie-Smith (1914) recorded that fairy prions were present in thousands in 1911. Richdale (1944b: 32–33) found them "present, though sparsely" in late August 1941, and again in late August 1942 could have "picked up some dozens". In May 1942 and 1943 Richdale "failed to observe the presence of this species in any of the bird remains left by cats", but on Whero Island where cats were not present and more than 800 fairy prions bred Richdale saw none from 10 to 17 May 1941.

In December 1968 Adams and Cheyne found "a very large population of this species — most common breeding petrel" and banded 100 birds. They were present in June–July 1970 and some fresh, cat-eaten birds were seen. They were the main source of food for cats and were the most frequent species in cat droppings.

Sooty Shearwater (*Puffinus griseus*). Guthrie-Smith (1914: 40–41) thought there were no more than a few thousand sooty shearwaters nesting on the island. In May 1942, at the end of a poor nesting season for sooty shearwaters, muttonbirders took only 37 chicks between 11 and 21 May, about 50% of the normal catch (Richdale 1945: 49). This suggests that only a few hundred sooty shearwaters nested on Herekopare Island in the early 1940s. In December 1968 Adams and Cheyne found "not a terrifically large number coming in", and banded 10 birds. In 1970 dead, cat-eaten birds were numerous.

Diving Petrel (*Pelecanoides urinatrix*). The description given by Guthrie-Smith (1914: 24) suggests that a vast population of diving petrels bred on the island. "They reached the island in dozens, scores, hundreds, thousands, hundreds of thousands, and I verily believe perhaps in millions." Guthrie-Smith (1914: 27) considered that diving petrels formed the majority of the seabirds nesting on Herekopare Island.

Richdale (1943: 24), after visiting the island in August 1941 and May 1942, considered that a great many diving petrels still existed on Herekopare Island. In August 1942 during 3 nights, 100 were picked up for measuring (Richdale 1943: 25) and in 1 h during one evening, 106 were counted coming in to land. In May 1942 no sign of diving petrels was found on Herekopare Island or on Whero Island and observations suggested that they do not usually visit land after the end of the breeding season. On 9 May 1943 the remains of a diving petrel killed by a cat the previous evening were found, but no more were found on the six following days (Richdale 1945: 42).

Adams and Cheyne did not record diving petrels in December 1968 and they were not seen in 1970 although muttonbirders report that they are still present. No remains of diving petrels were found in the cat scats.

Pied Shag (*Phalacrocorax varius*). Guthrie-Smith (1914: 15) recorded the pied shag, and "another species of shag". In December 1968 Adams and Cheyne recorded three pied shags fishing from rocks on the reef to the north of the island. They were occasionally seen fishing and roosting around the coast in 1970 but no evidence was found that the birds nest on Herekopare Island.

Blue Shag (*Stictocarbo punctatus steadi*). Blue shags were occasionally seen fishing and roosting around the coast. They possibly nest on the cliffs on the southeast side of the island.

Harrier (*Circus approximans*). Guthrie-Smith (1914: 15) recorded a harrier nest on Herekopare Island composed entirely of the skeletons of detached wings of fledgling diving petrels. In 1970 five harriers accidentally caught in the cat traps were banded and released; two were recaptured. Never more than two birds were seen over the island at any one time.

Banded Rail (*Rallus philippensis*). Mrs Willa, (pers. comm.) last saw a banded rail on Herekopare Island about 1924. Neither Guthrie-Smith nor subsequent visitors recorded it but banded rails are inconspicuous birds and may have been overlooked.

Stewart Island Weka (*Gallirallus australis scotti*). Guthrie-Smith (1914: 15–16) reported that in January 1911 "one weka was heard ... they are very scarce" and they were not seen about the hut. Muttonbirders report that wekas were introduced about 1928 and were first taken for food in 1930 (Mr P. R. Willa, pers. comm.). However, C. M. Miskelly (pers. comm.) was told by several muttonbirders that wekas were introduced in the early 1920s. Edgar Stead and R. A. Wilson visited Herekopare Island in 1932 but Wilson (1959) does not mention that they saw wekas. This is surprising, because he considered that wekas were just as destructive as cats on the muttonbird islands, as he observed on Jacky Lee Island. Richdale made several visits between 1941 and 1943 and in most of his writings does not mention wekas. However, in his letter to The Southland Times of 17 January 1944, after a visit to Herekopare Island, he wrote that cats pulled the petrel chicks out of the burrows and that "after the heads had been chewed off, the bodies were left to be devoured by wekas". Some time after 1941 the muttonbirders decided to remove the wekas as they were damaging muttonbirds killed by birders and left on the tracks. In one muttonbird season following this 300 wekas were killed. Wekas were not recorded by Adams and Cheyne in 1968 or in 1970.

Variable Oystercatcher (*Haematopus unicolor*). In December 1968 Adams and Cheyne recorded oystercatchers flying around the coast. A few birds frequented the eastern shores in 1970.

Stewart Island Snipe (*Coenocorypha aucklandica iredalei*). C. M. Miskelly (pers. comm.) determined, by interviewing muttonbirders who had been on Herekopare in the 1920s, that snipe were present there until at least 1924 but were probably exterminated by cats and wekas soon afterwards.

Southern Skua (*Stercorarius skua*). Guthrie-Smith (1914: 38–39, 44) recorded two pairs of skuas with chicks in late November 1911 at the north end of the island. Richdale (1965: 11) recorded a nest with three adults and one chick on 6 January 1944. Adams and Cheyne recorded three pairs (one with a chick) breeding in December 1968. Two birds were seen in 1970.

Black-backed Gull (*Larus dominicanus*). Guthrie-Smith (1914: 44) found many black-backed gulls nesting on the west shore at the base of the cliffs. Adams and Cheyne in December 1968 saw them off the coast. In winter 1970 moderate numbers were seen following fishing boats but only a few birds were roosting on the island.

Red-billed Gull (*Larus novaehollandiae*). Red-billed gulls were recorded by Guthrie-Smith (1914: 15, 21) who suggested from their behaviour that they bred on the island. In December 1968 Adams and Cheyne recorded 15 pairs breeding in the tern colony on the southwest point of the island. In 1970 they were seen in moderate numbers following fishing boats and were occasionally seen roosting around the shore.

White-fronted Tern (*Sterna striata*). Guthrie-Smith (1914: 15, 21) recorded white-fronted terns possibly breeding. In December 1968 Adams and Cheyne recorded about 150 pairs breeding in a colony on the southwest point of the island.

New Zealand Pigeon (*Hemiphaga novaeseelandiae*). Guthrie-Smith (1914: 15) recorded pigeons in 1911. In 1970 pigeons were seen flying to other islands. A flock of six birds was seen to fly from Stewart Island towards Herekopare Island and then return towards Stewart Island, and a group of four towards Jacky Lee Island. One bird was mist-netted and released.

Red-crowned Parakeet (*Cyanoramphus novaezelandiae*). Red-crowned parakeets were not mentioned by Guthrie-Smith (1914); Richdale was reported in the Southland Times on 23 May 1942 as stating that they had disappeared. B. A. Vercoe visited the island in April 1943 and recorded three parakeets. They were present in moderate numbers in 1970; flocks of up to eight birds were seen and two birds were mist-netted and released.

Yellow-crowned Parakeet (*Cyanoramphus auriceps*). Guthrie-Smith (1914: 15) recorded in January 1911 that "in the vicinity of the hut many Yellow-fronted parakeets were feeding". Richdale was reported in the Southland Times on 23 May 1942 as stating that "the yellow-headed parakeets have disappeared". None was seen in 1970.

Long-tailed Cuckoo (*Eudynamys taitensis*). Guthrie-Smith (1914: 15) recorded that they were very plentiful and very noisy. In December 1968 Adams and Cheyne reported several seen and heard.

Morepork (*Ninox novaeseelandiae*). Moreporks were recorded by Guthrie-Smith (1914: 55). Observations on Cuvier Island (T. G. Lovegrove pers. comm.) suggest that this species is quite capable of visiting Herekopare Island from Stewart Island.

Kingfisher (*Halcyon sancta*). One kingfisher frequented the northeast coast of the island in 1970.

Hedgesparrow (*Prunella modularis*). Hedgesparrows were recorded by Adams and Cheyne in December 1968 as not common. They were present in moderate numbers in 1970; seven were mist-netted, measured, banded and released.

Stewart Island Fernbird (*Bowdleria punctata*). Fernbirds were recorded by Guthrie-Smith (1914: 15). Richdale, in newspaper reports (Otago Daily Times, 15 October 1941: 7; Southland Times 23

May 1942: 4) stated that the fernbird had already gone. Muttonbirders confirmed that the fernbird was present on Herekopare Island but could give no indication of when it was last seen.

Brown Creeper (*Finschia novaeseelandiae*). Guthrie-Smith (1914) recorded brown creepers nesting, and B. A. Vercoe recorded seeing them when he visited the island in 1943. They have not been recorded since.

Grey Warbler (*Gerygone igata*). Grey warblers were recorded by Guthrie-Smith (1914: 55); and as "not common" by Adams and Cheyne. They were present in low numbers in 1970; two birds were mist-netted.

Fantail (*Rhipidura fuliginosa*). Richdale [1949] recorded a black fantail on Herekopare Island. In 1970, fantails were present in relatively low numbers. Two birds were caught and banded and one of them was seen the next day on the other side of the island, about 575 m distant.

Tomtit (*Petroica macrocephala*). Tomtits were recorded by Guthrie-Smith (1914: 15). Richdale, in newspaper reports (Otago Daily Times, 15 October 1941: 7; Southland Times, 23 May 1942: 4), stated that the tomtit had disappeared from Herekopare Island. It was recorded again in 1970 in low numbers; two birds were mist-netted.

Stewart Island Robin (*Petroica australis rakiura*). Robins were recorded nesting by Guthrie-Smith (1914: 38). Richdale, in newspaper reports (Otago Daily Times, 15 October 1941: 7; Southland Times, 23 May 1942: 4) stated that "the robin has already gone"; it has not been recorded subsequently.

Song Thrush (*Turdus philomelos*). There were few thrushes present in 1970; three were caught.

Blackbird (*Turdus merula*). Adams and Cheyne reported blackbirds as common in December 1968. Few were present in 1970; two were caught.

Silvereye (*Zosterops lateralis*). Silvereyes were recorded by Guthrie-Smith (1914: 15) in 1911. They were by far the most common bird on the island in winter 1970. Twenty-nine birds were caught in four days in a mist-net placed beside a waterhole. These were banded and released. A further 34 unbanded and 4 banded birds were caught over the next three days.

Bellbird (*Anthornis melanura*). Bellbirds were recorded nesting in November 1911 by Guthrie-Smith (1914: 38). Adams and Cheyne in December 1968 considered that it was the most common of the native species but was not in high numbers. Present in moderate numbers in 1970; 13 were mist-netted.

Tui (*Prosthemadera novaeseelandiae*). Tuis were recorded by Guthrie-Smith (1914: 15). Adams and Cheyne reported tuis as being numerous in December 1968, but very few were seen in winter 1970.

Yellowhammer (*Emberiza citrinella*). One yellowhammer was seen in 1970.

Chaffinch (*Fringilla coelebs*). Very few chaffinches were seen in 1970.

House Sparrow (*Passer domesticus*). One house sparrow was seen and caught in 1970.

Starling (*Sturnus vulgaris*). In December 1968 Adams and Cheyne saw several small groups of starlings and found them nesting in bluffs on the western side of the island. In 1970 they were present in moderate numbers, especially on the steep grass-covered slopes on the northwest side of the island.