Changes in bird numbers on Raoul Island, Kermadec Islands, New Zealand, following the eradication of goats, rats, and cats

C.R. Veitch1, C. Gaskin2, K. Baird3, and S.M.H. Ismar4
148 Manse Road, Papakura, New Zealand. <dveitch@kiwilink.co.nz>, 2400 Leigh Road, RD5, Warkworth, New Zealand. 3Royal Forest and Bird Protection Society of NZ, P.O. Box 108055, Symonds Street, Auckland, New Zealand. 4University of Auckland, School of Biological Sciences, PB 92019, Auckland, New Zealand.

Abstract Raoul Island (2938 ha; 29°16'S, 177°52'W) is the largest island in the Kermadec Group and is situated 995 km from the nearest part of mainland New Zealand. It is the summit of a large and active volcano rising from the Kermadec Ridge. The forest on Raoul is dominated by Kermadec pohutukawa (Metrosideros kermadecensis) with an understory of broad-leaved fruit-bearing plants, ferns and palms. Prior to the introduction of browsing and predatory mammals, Raoul had an abundant seabird population and a limited landbird population of endemic and native species. Several exotic landbird species established following their introduction to mainland New Zealand in the late 1800s, which was also after the introduction of several species of mammals to Raoul. The introduced mammals reduced seabird populations to possibly only two species continuing to breed in low numbers on Raoul. The forest became a canopy with little understory. Some forest bird species declined in number while others increased; at least three species became extinct on Raoul. Following eradication of all the introduced mammals, seabirds are returning to the island; we report sightings of 11 seabird species on Raoul, with evidence of breeding in black-winged petrels (Pterodroma neglecta), wedge-tailed shearwaters (Puffinus assimilis kermadecensis), Kermadec petrels (Pterodroma cervicalis), and white-naped petrels (Puffinus pacificus) are prospecting. Some forest bird species have declined in number while others have benefited from improved forest condition.

Keywords: Monitoring, Capra hircus, Norway rat, Rattus norvegicus, Pacific rat, Rattus exulans, Felis catus

INTRODUCTION

Raoul Island (2938 ha; 29°16'S, 177°52'W) is the largest island in the Kermadec Group and is situated 995 km from the nearest part of mainland New Zealand (East Cape) (Fig 1). The island is roughly triangular in shape, approximately 10 km long and 7 km wide and rises to 516 m at Mt Moumoakai. Its topography consists of a steep-sided central caldera with major ridges to the west and south from which run sharply dissected ridges and ravines. A boulder and rock coastline flanked by cliffs up to 250 m in height surrounds most of the island, although sand and gravel beaches occur at Denham Bay and to a lesser extent on the north coast in front of Low Flat and the Terraces. Flat to undulating land is essentially restricted to Denham Bay, Low Flat, the Terraces and to the floor of the caldera. Three lakes occur on the floor of the caldera; the largest being Blue Lake, followed by Green Lake, and Tui Lake. The lakes are periodically affected by volcanic activity and do not provide a consistently potable water source. Standing water also occurs in the centre of the Denham Bay flat, and freshwater springs occur at the western end of the Terraces and on the coast north of Lava Point.

Fig. 1 Raoul Island. The areas marked in bold show the distribution of black-winged petrels as at February 2010.

Forest on Raoul Island is dominated by Kermadec pohutukawa (Metrosideros kermadecensis) with Myrsine kermadecensis and Ascarina lucida var. lanceolata as the predominant understory. Other common species include maho (Melicystis ramiflora), wharangi (Melicystis ternata), kawakawa (Macropiper excelsum var. majus), karaka (Corynocarpus laevigata), the tree ferns Cyathea kermadecensis and C. milnei, and nikau palm (Rhopalostylis cheesemani) (Sykes 1977).

Raoul Island has a mild subtropical climate, with a mean annual temperature of 19°C and only small seasonal and daily temperature ranges. The maximum temperature recorded is 28.3°C, and the minimum 7.4°C; frosts are unknown. Rainfall averages 1535 mm, evenly distributed throughout the year (Anon 1979). South-easterly and easterly winds predominate in summer, and north-west easterlies at other seasons (Williams and Rudge 1969).

Adjacent to Raoul are eight islands large enough to sustain vegetation, and a number of smaller stacks. These lie off the north-east coast of Raoul, and in Boat Cove (Fig 1). These islands are all free of introduced predatory or browsing mammals and there are no signs that they have been subjected to fire. Introduced weeds are present on the Meyer Islands.

Macauley Island (306 ha; 30°15'S, 178°32'W) lies 108 km south-south-west of Raoul. Curtis and Cheeseman Is. and L’Esperance Rock are further to the south.

The data presented in this paper come from occasional field expeditions and New Zealand Department of Conservation records. For the most part they were not gathered to specifically record the pre- and post-eradication bird populations, but rather as an ongoing record of the avifauna. Since 2007 a more detailed effort has been made to document avian recolonisation and breeding populations through island-wide searches (Ortiz-Catedral et al 2009; Ismar et al 2010; Gaskin in press), and in conjunction with the New Zealand Department of...
Conservation (DOC) weed programme, and Raoul staff observations. The purpose of this paper is to provide as accurate as possible baseline data for future investigations, with respect to both seabirds and terrestrial species in the context of changes to an unusual bird fauna as it recovers from major biological disturbance through predation and habitat modification.

The Kermadec Islands have no indigenous land mammals or herpetofauna. On Raoul Island, Polynesian voyagers introduced Pacific rats (Rattus exulans), probably from the southern Cook Islands, possibly earlier than A.D. 1250, and, evidence suggests also at a later date, from New Zealand (Matisoo-Smith et al. 1998, 1999). Cats (Felis catus) were established on Raoul by 1836 (Straubel 1954), and Norway rats (R. norvegicus) probably arrived when the schooner Columbia River was wrecked in 1921 (Ingram 1972; Merton 1968).

In the period between their introduction prior to 1836 (Straubel 1954) and their removal in 1972-85 (Parkes 1990), goats (Capra hircus) modified the vegetation considerably (Sykes 1969). They removed almost all natural understory, allowing little or no regeneration of canopy species, and permitting dense stands of the introduced aroid Aloussia brisbanensis to flourish. Many coastal slopes became grasslands. The significant reduction of goat numbers from the early 1970s allowed extensive regeneration of vegetation to occur. The bare parts of the forest floor became covered in a dense layer of litter (Fig 2). However, the continuing presence of rats and lack of seed-dispersing birds inhibited seedling growth and species diversity in most places (West 2011).

Domestic pigs and dogs have been present, but did not establish as feral populations. Both would have had an impact on ground-nesting birds.

Until the mid 1980s, the Terraces were grazed by sheep and cattle, but these have now been removed from the island. For the most part, the old farm is now rank grass, which provides little food or habitat for most birds. A small mown airstrip is utilised by a number of bird species.

Rats and cats were eradicated from Raoul Island in 2002 and 2004, respectively (Broome 2009).

The native forest avifauna of Raoul has strong connections to the avifauna of New Zealand. Since European colonisation of New Zealand, further forest and waterbird species have reached Raoul Island. The introduced mammalian predators, with forest modification by the goats, has changed the relative abundance of these species and caused the extinction of at least three species from Raoul Island (Veitch et al. 2004).

Nesting seabirds were extremely abundant on Raoul in the past. For example, Iredale (1910) recorded “immense numbers” of wedge-tailed shearwaters (Puffinus pacificus) and “about half a million” Kermadec petrels (Pterodroma neglecta). White-naped petrels (Pterodroma cervicalis) were also present at the time of Iredale’s visit, but evidence of cat predation was notable (Bell 1910). By that time seabird populations are likely to have been greatly reduced by cat and rat predation, with smaller species either extirpated or severely reduced (Gaskin in press). Seabird chicks and eggs were also harvested for food by settlers and visiting sailors up to the 1930s (Bacon 1957); even their down and feathers were used to stuff pillows and mattresses (Large 1888).

By the end of the twentieth century Raoul was practically devoid of seabirds (Veitch et al. 2004).

By 2000, Kermadec petrels, white-naped petrels, and Kermadec storm petrels were not recorded on Raoul. Burrows attributed to wedge-tailed shearwaters, Kermadec little shearwaters (Puffinus assimilis kermadecensis), and black-winged petrels (Pterodroma nigripennis) were occasionally found but those that were checked for breeding activity were found to be empty. It is possible that a few red-tailed tropicbirds (Phaethon rubricauda) nested successfully on remote cliff-ledges; sooty terns (Onychoprion fuscatus) remained in small colonies on the northern beaches in the 1990s; and a few white terns (Gygis alba) could be seen along southern coasts and at the forest edge behind the northern terraces.

METHODS

Forest Bird Counts

Forest bird counts on Raoul Island were instigated by Don Merton in January 1967 (Merton and Veitch 1986) during the Ornithological Society of New Zealand visit and have been repeated by Dick Veitch in 1994, 1998 (Veitch 2003), and 2008. The counting protocol consisted of one minute stops and four minute walking counts along each transect. All birds seen or heard within 100 metres were counted. Each transect was counted once in each year.

In 1967 these transects were three hour walks on two routes south of Mt. Prospect (Fig. 1) and along the Boat Cove Road. Forest changes following goat eradication made a repeat of the Mt. Prospect transect impossible in 1994, so a track that was cut between Trig V and the Hutchinson Bluff Track (the Top Track), and the Boat Cove Road were counted instead. These two transects were also used for the 1998 and 2008 counts.

The time of year when the counts were made has varied: January 1967; June/July 1994; July 1998; March/April 2008.

Seabird Observations

Since eradication of all mammalian predators and pests by 2004, surveying for seabird breeding has been undertaken spasmodically, with evidence gathered by Department of Conservation (DOC) staff during weeding programmes and casual hiking expeditions. There has also been an annual sooty tern survey (Potier and Shanley, Internal DOC report, 2009), and by K. Baird (KB), S. Ismar (SI), and C. Gaskin (CG). Surveys of known black-winged petrel and little shearwater colonies and more general island searches to find breeding seabirds were undertaken during visits from October 2006 to April 2008.

![Fig. 2 Forest birds counted (mean number per minute) on Raoul Island. Note that counts were undertaken at different times of the year: Jan 1967, Jun/Jul 1994, Jul 1998, and Mar/Apr 2008.](image-url)
RESULTS

The data obtained from the four sets of forest bird counts from 1967 to 2008 are shown in Fig. 2. No statistical analysis of these counts was possible. Various methods were tested to portray the data and all resulted in showing the general picture. This is a good portrayal of the counts but not a realistic record of forest bird numbers, particularly in 2008. Details of each species are included in the species accounts below.

Wedge-tailed shearwater (Puffinus pacificus). The first evidence of wedge-tailed shearwater breeding on Raoul after predator eradication was in May 2007, when two live chicks close to fledging were found on the beach near Fleetwood Bluff. Eight burrows, at least five of which had been active, were subsequently detected in the cliffs at this area. By 2008, the number of burrows at this site had increased to eleven, with eight active as judged by guano splashes around the entrances. Burrow entrances could be seen on cliffs west of the initially detected colony, but it could not be confirmed if they held chicks or had been frequented by adults. An additional breeding site was found a little further to the west, with seven burrows, at least five of which were holding chicks (SI, CG). In April 2008, a wedge-tailed shearwater was found prospecting at the entrance of one of the black-winged petrel burrows on the Hostel Cliffs (SI).

Kermadec little shearwater (Puffinus assimilis kermadecensis). Seen flying near the Hostel and one individual was found in the guttering of the Hostel in September 2007 (DOC staff notes).

Black-winged petrel (Pterodroma nigripennis). DOC volunteers first detected re-colonising black-winged petrels in the Coral Bay and Crater Lake Track areas on Raoul Island in 2006. After that, four breeding areas of the species were located in a survey in May 2007. By this time, the black-winged petrel had established breeding colonies on the slopes over Coral Bay, in woody areas around the Crater Lake Track, on the grassy northern cliff faces close to the Hostel, and in grassy areas behind the Hostel (Ismar et al. 2010). By March 2008, these breeding areas had extended, except for Coral Bay. New burrows were found at many locations along the northern slopes (Ismar et al. 2010). DOC staff camping at D’Arcy Point in 2008 reported many black-winged petrel burrows and birds landing amongst them at night. In 2008, CG found burrows at Smith’s Bluff, Wilson’s Point and Hutchison’s Bluff. Birds were seen entering forest on ridges in the vicinity of Sunshine Valley and D’Arcy Point. In January 2010, DOC staff reported finding new burrows across the northern slopes during their weeding programme (SI). The known distribution by January 2010 is shown in Fig. 1.

Kermadec petrel (Pterodroma neglecta). Large numbers of summer-breeding Kermadec petrels formerly bred on Raoul Island. There has been one recent record of breeding with a large chick found at Nash Point on Raoul Island in September 2006 (DOC staff notes).

White-naped petrel (Pterodroma cervicalis). Now confined as a breeding species to Macauley Island but individuals of this species were recorded in February 2005 and 2006 caught in velcro grass (Cenchrus calyculatus Cav.) on the northern terraces of Raoul Island (DOC staff notes). It is also known from at-sea observations to be in waters around Raoul Island in May (Gaskin in press.).

Kermadec storm petrel (Pelagodroma albirostis). Individuals flew onto the Hostel veranda on two separate occasions (29 May 2008 and 24 August 2008), indicating that prospecting is possibly occurring (DOC staff notes) or the birds were attracted to the Hostel lights.

Red-tailed tropicbird (Phaethon rubricauda). Thirty individuals were counted along the northern beaches and seen performing aerial display flights in 2007 (KB). In 2008 a similar number of birds, including some pairs, could be seen on cliff ledges leading to Hutchison Bluff, also performing aerial displays (CG, SI).

Great frigatebird (Fregata minor). This species has been reported in numbers (≤18 birds) (DOC Raoul staff Thirdly Reports); KB, CG (pers. obs. 2006, 2008) that suggest possible future breeding (G. Taylor, DOC, 9 June 2008 pers. comm.).

Spotless crake (Porzana tabuensis). This species was absent from Raoul in 1967 but is now present. In 2008, they were seen or heard in the dense grasses around the Hostel and along the back of the northern terraces. Spotless crakes have also been reported from the dense ferns behind the Denham Bay dunes.

Pukeko (Porphyrio melanotus) are now a common bird of the forest edges. In previous bird records they have either been present in low numbers or confirmed as absent (Veitch et al. 2004). They have increased in number since the removal of introduced mammals.

Sooty tern (Onychoprion fuscatus). Remnant populations probably remained on Raoul Island until cats were eliminated prior to 2004 (Broome 2009). In 1966/67 the Ornithological Society of New Zealand expedition estimated 40,000 pairs in Denham Bay and another 40,000 along the southern side of Hutchison Bluff (Veitch et al. 2004). By 1995 just 2230 birds were counted during the breeding season at Denham Bay, but by 1997 none were at Denham Bay and few were elsewhere on the coast of Raoul (Veitch et al. 2004). By 2006 sooty terns were breeding on the beaches to the north of Hutchison’s Bluff and apparently expanding their colony each year. Estimates of population size by DOC were hampered by methodological problems and the desire not to negatively impact breeding birds, made difficult by the long narrow stretches of beach. An estimate was made during the 2008/2009 breeding season by two volunteers (Potier and Shanley, Internal DOC report 2009). Using a density estimate from quadrats where nests were counted and extrapolating for the measured size of the colony they estimated between 7634 and 9330 birds breeding on Raoul Island. There is no evidence yet (2010) of sooty terns returning to their former stronghold at Denham Bay (KB).

Grey noddy (Procellaria cerulea). Possibly breeding, certainly use Raoul Island cliffs at Hutchison Bluff and Boat Cove for roosting (KB, CG, SI).

White tern (Gygis alba). Up to 12 individuals seen between Boat Cove and Sunshine Valley in 2007 (CG, KB) and chick-feeding observed on one occasion at Boat Cove (KB).

New Zealand pigeon (Hemiphaga novaeseelandiae), which were recorded by early settlers (Veitch et al. 2004) continue to be absent from the Kermadec Islands. There is now an abundance of food suitable for pigeons and they should now be considered for re-introduction to Raoul, as originally suggested more than 20 years ago (M. Clout pers. comm.).

Kermadec parakeet (Cyanoramphus novaeseelandiae cyanurus). After the eradication of goats, parakeets were heard daily in the forest but numbers were low and breeding considered unlikely. There was a significant increase after
the eradication of rats and cats, and breeding was proven in 2008 (Ortiz-Catedral et al. 2009). In 2008 they were present for the first time in the forest bird counts, but were quiet and very tolerant of counter presence. On many occasions they were seen to fly from the ground to perches three to five metres from the track and just sit there quietly while the counter passed by.

**Long-tailed cuckoo** (*Eudyptes taitensis*) were seen during the April 2008 visit, one bird was seen in clear view at Denham Bay near the hut (KB, CG, SI), and in forest on the Mt. Prospect track (above Tui Lake) (CG).

**Sacred kingfisher** (*Todiramphus sanctus*) abundance has diminished. In 2008, CRV did not see any along roads and at their previous forest-edge locations, however CG and SI did observe them along the north coast towards Hutchison Bluff, and on the northern terraces.

**Welcome swallow** (*Hirundo neoxena*) continue to be present seasonally, many in summer and possibly absent for parts of the winter, but with no indication of nesting. Previously we have attributed this to depauperate invertebrate food sources, but the removal of rats has allowed a notable increase in insect abundance.

**Blackbird** (*Turdus merula*) appear to have diminished in the denser, darker, forest areas but have increased elsewhere, possibly due to increased food abundance. In 2008 they were notably more abundant on the cleared surface of Boat Cove Road and elsewhere and would give their alarm call before flying well away from the count area. Often their point of departure would be from points close to the counter, but out of sight.

**Song thrush** (*Turdus philomelos*) rarely called and would fly away from the track. Their rapid wing-beats were often the only indication of their presence.

**Tui** (*Prosthemadera novaeseelandiae*) numbers increased with the improving floristic diversity following goat eradication. During the 2008 counts they were very quiet. Whether this was due to the time of year, or whether tui numbers were seriously depleted by a recent spate of mortality observed by Raoul Island staff, is not known. High numbers of dead tui have been observed on at least two occasions in the last few years (K.B. pers obs, 2008, 2009). Necropsies carried out on these birds indicate starvation as a factor in their deaths. Low natural food diversity combined with release from predation pressure and storm events affecting food supplies are possible contributors to these mortality events. Loss of food supplies such as berries and pohutukawa flowers after storm events has been observed (K.B. pers obs, 2008)

**Yellowhammer** (*Emberiza citrinella*) were relatively common in open areas of goat-browsed vegetation. They diminished in number following goat eradication, but appear to have increased again following rat and cat eradication.

**Starling** (*Sturnus vulgaris*) were the most abundant bird in the forest in 1967 but declined markedly following goat eradication and forest understory growth. During counts they are often not seen initially but commonly give their short alarm call before flying well away from the count area. DV also repeated counts of starlings flying to roost on the Meyer Islands. This suggested an 80% decline in the number of starlings using that roost. With rats now removed from Raoul it is possible that starlings are learning to roost on Raoul.

**Other birds** There is no evidence that Tasman masked booby (*Sula dactylatra tasmani*), black noddy (*Anous minutus*), brown noddy (*A. stolidus*), and white-bellied storm petrel (*Fregata grallaria*) are prospecting Raoul. The former two are commonly seen flying along the shoreline or feeding just offshore, and both breed on the Meyer and Herald Islands.

During past visits to Raoul a number of self-introduced passerines have been recorded in low numbers in the forest or at the forest edges. Silvereye (*Zosterops lateralis*), greenfinch (*Carduelis chloris*), goldfinch (*C. carduelis*), and common redpoll (*C. flamma*) were not recorded during the 2008 visit and the condition of the Raoul Island forest leaves little space for them.

**DISCUSSION**

The forest bird counts were started at a time when we hoped the goats could be removed. Cat eradication had been achieved on small islands and rat eradication was not considered possible. Thus the possible changes of forest condition and bird abundance were not considered in these early data records.

In 1967, we were easily able to count the 100 m wide transect and expected to see, or disturb, all birds on the forest floor and up to the forest canopy. In 1994 and 1998, there was a notable change with the forest floor now being a dense litter layer (Fig. 3), and some fruit-bearing plants increasing in abundance. Total bird numbers had clearly increased, but the density of ground cover may have reduced the opportunity to count some species. By 2008, the forest regeneration had reached a point where many birds were difficult to see. On the Boat Cove Road average visibility was less than 10 metres, both overhead and to the sides, and within that distance (apart from the road surface) the ground cover was sufficient to hide any birds that were on the ground. On the Top Track, average visibility was less than five metres, both overhead and to the sides, and within that distance most of the ground cover was sufficient to hide any birds that were on the ground.

Increased forest density and seasonal changes of bird behaviour meant that in 2008, the most vocal birds were counted far more frequently than the quieter species, and these results are not readily comparable to previous counts.

The eradication of all mammals is allowing a return towards a natural ecosystem, although exactly how and which birds will colonise Raoul is something that only future studies will reveal. Changes of forest bird abundance are
similar to those seen in other island ecosystems following the removal of browsing mammals and cats (Diamond and Veitch 1981) but with a further possible influence resulting from increased insect abundance following rodent eradication.

Forest health and management of bird-dispersed invasive plants has reached a level where re-introduction of the New Zealand pigeon can now be considered. Management of the duck population to retain Raoul Island as a grey duck (Anas superciliosa) area should also be considered.

With respect to seabirds, black-winged petrels appear to be making a rapid return with multiple colonies becoming established on steep slopes in the drier forested areas; sooty terns have become well-established in the Hutchison’s Bluff area (Ismar et al, 2010). Red-tailed tropicbirds appear to be nesting on high cliffs, also in the Hutchison’s Bluff area. A more gradual return is evident in other species: after six years there is only one confirmed Kermadec petrel breeding record, despite large numbers of the birds on the Meyer Islands and only two white-naped petrels have been seen since the eradication (Gaskin in press). Sound broadcast systems should be maintained as the primary method of attracting seabirds back to Raoul Island, but a time limit should be five years from system set up. We recommend that if by 2013 white-naped petrel and Kermadec little shearwater have not established on Raoul Island, chick translocations should be considered.

DOC has established a presence/absence monitoring system for seabirds to be undertaken at the same time as weed eradication work on about 25% of Raoul Island. Monitoring of seabirds, particularly species most at risk and endemic to the region, on all islands in the group on a regular basis is important to understand the health and recovery of the populations of seabirds.

Of equal importance is the requirement to ensure that biosecurity is maintained on all islands in the group. Monitoring for rodents is a primary concern, but there is also potential for introduction of other invasive species.

ACKNOWLEDGEMENTS

We thank the Department of Conservation for landing permits, extensive support of the work, and accommodation during our stays on Raoul Island. The National Institute of Water and Atmospheric Research (NIWA) and the Royal New Zealand Navy provided transport to the islands. Funding for the work was provided by Education New Zealand through an International Doctoral Research Scholarship and by the Faculty of Science, University of Auckland, to SMHI.

REFERENCES


Bacon, A. 1957. Raoul adventures. Reminiscences written at the age of 86 years (unpublished). 32p. [Copy held at Waitakere Area Office, Department of Conservation]


