Long-term management of kakerori (*Pomarea dimidiata*) in the Cook Islands

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DOC RESEARCH & DEVELOPMENT SERIES 313

Published by
Publishing Team
Department of Conservation
PO Box 10420, The Terrace
Wellington 6143, New Zealand

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.
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ISSN 1176–8886 (hardcopy)
ISSN 1177–9306 (web PDF)
ISBN 978–0–478–14640–0 (hardcopy)
ISBN 978–0–478–14641–7 (web PDF)

This report was prepared for publication by the Publishing Team; editing and layout by Lynette Clelland. Publication was approved by the General Manager, Research and Development Group, Department of Conservation, Wellington, New Zealand.

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ABSTRACT

The kakerori (*Pomarea dimidiata*) population had fallen to 29 birds in 1989, before rat poisoning began within 155 ha of forested hill country in the Takitumu Conservation Area (TCA), in southeastern Rarotonga. The population had rebounded to 255 birds by 2001 when management shifted from 'recovery' to 'sustainable management' of the population at 250–300 individuals. The key elements were to reduce rat poisoning effort so that recruitment of kakerori balanced annual mortality, and to establish an 'insurance' population on Atiu, by transferring 30 subadults between 2001 and 2003. In 2001, baiting was reduced from three to one baits per bait station; and from 2003, baits were replenished fortnightly rather than weekly. Labour costs fell 43% to 32 person days per year and Talon® (brodifacoum) rat poison costs fell 25%. Despite the reduced poisoning effort and the transfers, 281 birds were recorded on Rarotonga in 2004. Five tropical cyclones passed through the southern Cook Islands in February–March 2005, causing considerable damage. Although annual mortality was higher than usual, the worst effect became apparent in the following breeding season, when nest predation by rats was unusually high, and the damaged canopy cover left nests exposed to the elements. The population on Rarotonga fell to 254 birds in 2006, so 'interim' poisoning was introduced in April and in July 2007 to improve adult survival and further reduce rat numbers. By 2007, the population had increased to 314 birds; 271 on Rarotonga and 43 on Atiu. Profits generated by the TCA's ecotourism business should be sufficient to sustain the current management of kakerori. Outcome monitoring can reduce to an annual fledgling count, and a two-yearly population census.

Keywords: kakerori, *Pomarea dimidiata*, sustainable management, rat control, Rarotonga, Atiu

Robertson, H.A.; Karika, I.; Matearíki, G.; Nia, L.; Saul, E.K. 2009: Long-term management of kakerori (*Pomarea dimidiata*) in the Cook Islands. *DOC Research & Development Series 313*. Department of Conservation, Wellington. 22 p.

1. Introduction

In a review of bird conservation problems in the South Pacific, commissioned by the South Pacific Regional Environment Programme (SPREP) and the International Council for Bird Preservation (now BirdLife International) in the early 1980s, Hay (1986) identified the kakerori or Rarotonga flycatcher (*Pomarea dimidiata*) as one of the species most urgently in need of conservation management (Robertson et al. 1994).

The kakerori is a small (22-g) forest passerine which is endemic to Rarotonga. In the mid-1800s, kakerori were reported to be common throughout the island, but by the early 1900s they were thought to have become extinct. In the 1970s, a small population was rediscovered in the rugged inland hills of the island. In 1984, it was estimated that the population was about 25 birds; however, this estimate was low, because a thorough survey in 1987 found 38 birds.

Kakerori display an interesting variety of plumages, but it was not until birds were individually colour-banded that it was shown that males and females show the same set changes in plumage patterns: all yearlings are orange, with a yellow base to their bill; all 2-year-olds are orange, with a dark blue base to the bill; 3-year-olds are a variable 'mixed' colour, ranging from some females that are blotchy grey and orange, through to some males that are entirely grey apart from the odd orange feather; all birds 4 or more years old are entirely grey (Robertson et al. 1993).

Most 1- and 2-year-old kakerori form loose flocks or 'clubs' on the ridge tops, away from occupied territories; however, some join adults as 'helpers' to help to defend a territory and raise young. Most territories are in valleys, especially those sheltered from the prevailing south-east trade winds. Adult kakerori are strongly territorial and remain on their territory throughout the year. They breed from October to February, though most eggs are laid in October and early November. They lay 1–2 eggs in a bulky nest, often placed on a forked branch overhanging a waterway. Replacement clutches are laid if nests fail, but kakerori usually do not re-lay after successfully fledging young (Saul et al. 1998).

2. The kakerori recovery project (1989–2001)

As a result of a study between September 1987 and January 1988, Rod Hay and Hugh Robertson confirmed that the conservation status of kakerori was 'critically endangered' (Collar et al. 1994). They also reported to the Cook Islands Conservation Service (now Cook Islands Environment Service) and SPREP that ship rats (*Rattus rattus*) were having a very detrimental effect on the breeding of kakerori, and that cats (*Felis catus*) were likely to be predators of recently-

fledged juveniles and adult birds. The draft plan for the recovery of kakerori recommended a cost-effective experimental recovery programme targeting predators of kakerori, and scientific study aimed at assessing the effectiveness of this work (Hay & Robertson 1988).

The original objectives of the Kakerori Recovery Plan (Hay & Robertson 1988) were to:

1. Monitor, on an annual basis, the dynamics of the kakerori population on Rarotonga.
2. Research, develop and implement an effective predator (rat and cat) control programme.
3. Research, develop and implement a programme of managing the kakerori population by protecting nests, providing supplementary food and, as a last resort, translocation or captive breeding.
4. Describe the habitats used by kakerori, and determine the relationship between habitat features and the distribution of kakerori.
5. Develop and implement a programme of public education, awareness and participation in the kakerori conservation programme.
6. Encourage the protection of kakerori by creating a suitable reserve and developing appropriate national and international policies regarding the scientific collection or trade in kakerori, and the importation of wildlife (and, hence, potential predators, competitors, and diseases) into the Cook Islands.

In 1989, we started poisoning rats in the head of the Totokoitu Valley, where most of the remaining kakerori lived. The network of bait stations was expanded into the head of the Turoa Valley in 1990, and then into side valleys of the Avana Valley in 1991 and 1992 as the population expanded. Since 1993, we have run a network of up to 750 bait stations on four lines, one around the perimeter of the whole area along spurs and ridges, and three lines covering individual valleys. Poison baits ('Storm'® or Talon®: active ingredient brodifacoum) were placed in 40-cm lengths of 10-cm-diameter Novacoil® drainpipe from early September through to about December each year, to reduce rat numbers before and during the main part of the kakerori breeding season, which runs from mid-October to late December (Saul et al. 1999).

We compared breeding success in poisoned and unpoisoned areas each year. Every August, we mist-netted and individually colour-banded as many kakerori as possible, and conducted a population census by mapping the territories of kakerori in southeastern Rarotonga.

The Kakerori Recovery Plan was updated in 1995 by the Cook Island Environment Service (Saul 1995). This re-affirmed the above objectives, but changed the emphasis of Objective 3 by promoting a study of the feasibility of establishing an 'insurance' population of kakerori on another island in the southern Cook Islands which was free of ship rats (e.g. Aitutaki or Atiu).

In 1996, SPREP adopted a joint proposal by the Cook Islands Government and the Takitumu Conservation Area (TCA) Co-ordinating Committee (representing the three customary land-owning families) that the 155-ha TCA (Fig. 1), which is home for the kakerori, be adopted as a Conservation Area as part of the South Pacific Biodiversity Conservation Programme (SPBCP). The goal of the project

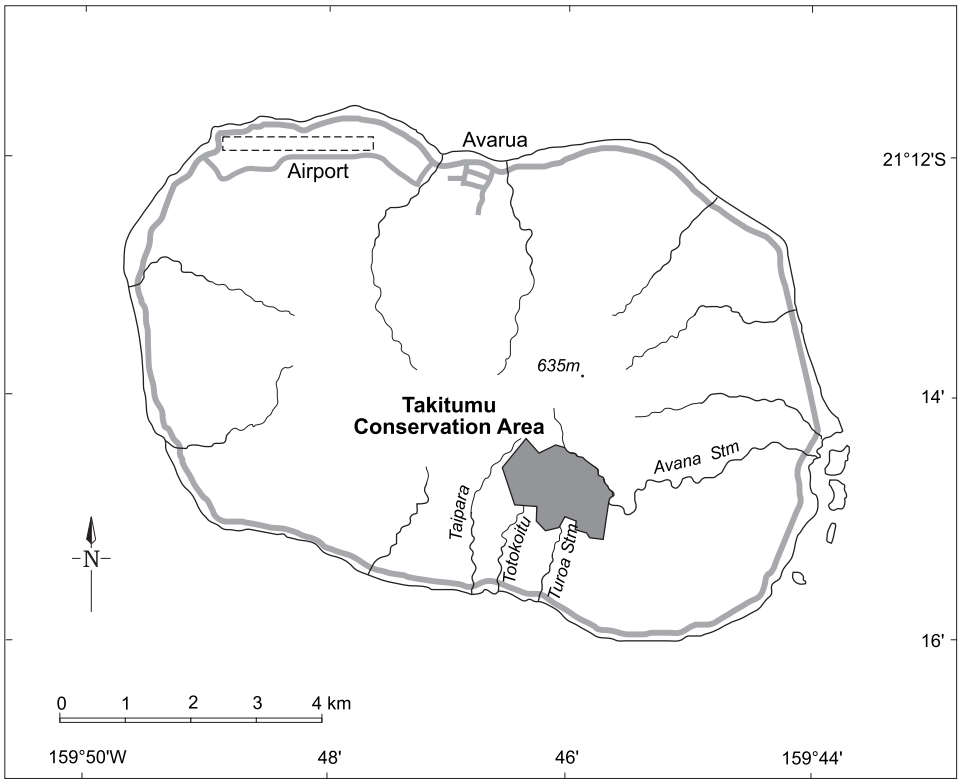

Figure 1. Map of Rarotonga showing the location of the Takitumu Conservation Area.

in the TCA was to 'conserve the Conservation Area's biodiversity for the benefit and enjoyment of present and future generations on Rarotonga'. More immediate objectives were to:

1. Develop partnership arrangements between government, landowners, non-governmental organisations and others for effective management and sustainable use of biodiversity in the TCA.
2. Develop and implement management plans for the wise use of biodiversity within the TCA.
3. Raise public awareness about the importance of and means for conservation of biodiversity in the TCA.
4. Promote, implement and support sustainable economic activities by communities associated with the TCA.
5. Develop, as appropriate, a model for the implementation of Conservation Areas in other parts of Rarotonga and the Cook Islands.

The TCA project was funded by the SPBCP for the 5 years from 1996 to June 2001, and received partial support for another year as the programme funding wound down. The project has attempted to continue its conservation endeavours mainly through running a landowner-led ecotourism venture. The main attraction of the TCA to international tourists is undoubtedly the kakerori and its management programme, but the area also hosts breeding populations of the other three species of native landbird and four of the six seabird species breeding on Rarotonga, a fruit-bat colony, several species of lizards, and several rare shrubs and orchids.

The Polynesian Avifauna Conservation Workshop identified the Kakerori Recovery Project as a flagship bird conservation project in Polynesia (Sherley 2001), and it is now being used as a model for other similar threatened species projects in the region. Because the scientific work underpinning the recovery

of kakerori is of wider application than just the management of the TCA, the Avifauna Conservation Project of SPREP supported the scientific costs of the project from 1999 to 2001. They also covered some of the costs associated with the first two of the three transfers of kakerori to Atiu to establish an 'insurance' population.

In 2001/02, with funding support from the Pacific Initiative for the Environment (a programme of the New Zealand Agency for International Development), the emphasis of management in the TCA shifted from the 'recovery' of kakerori to a programme aimed at investigating how to 'sustain' a viable population on Rarotonga at about 250 individuals, and ensuring that the 'insurance' population on Atiu was well established.

3. Kakerori population changes 1987–2002

In 1987, the kakerori population was 38 birds, but it dropped to 36 in 1988, and then to 29 in 1989 (Fig. 2). A population viability analysis showed that, at that rate of population decline, there was a 50% chance that kakerori would be extinct by 1998, and a 90% chance of extinction by 2002. An experimental programme of rat poisoning and nest protection was initiated in spring 1989, with careful measurement of the breeding success and survival of kakerori inside and outside of the treated areas. During each subsequent breeding season, rats have been poisoned in all or part of the 155 ha of steep forest country occupied by kakerori (Robertson et al. 1998). The effectiveness of the work has been measured by recording individual nest outcomes, fledgling productivity (Robertson et al. 1998; Saul et al. 1998), the survivorship of individually colour-banded kakerori, and by undertaking an annual census each August. The annual census has been made easier by adult birds generally remaining in the same territory year after year

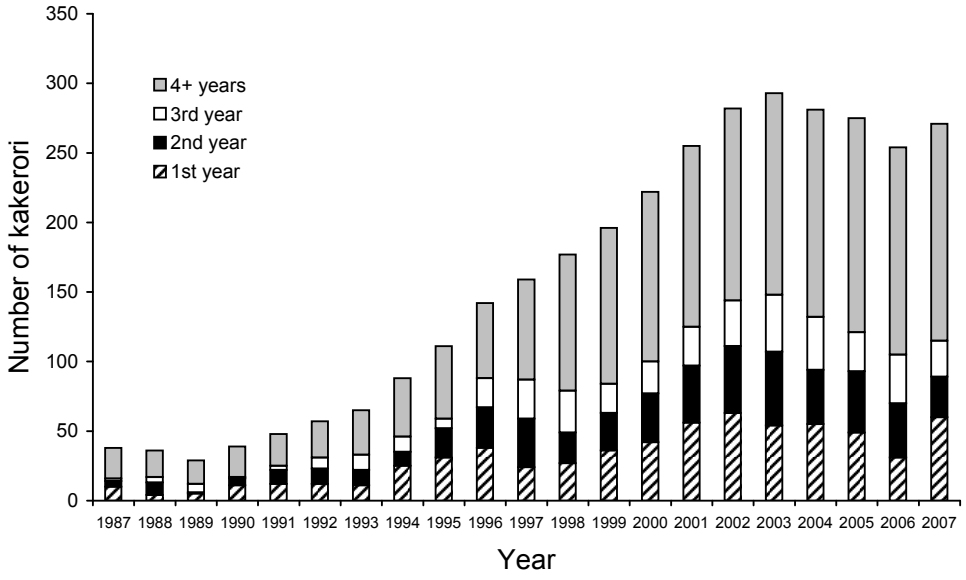

Figure 2. Annual pre-breeding census of kakerori, 1987 to 2007.

(Saul et al. 1998), and the progressive fixed changes in bill colour and plumage that kakerori experience during their first 4 years of life (Robertson et al. 1993), which has enabled the survival of unbanded birds to be estimated accurately. The kakerori population has increased each year from 1989, reaching 100 birds by 1995, 200 by 2000, and 282 birds (minus 10 transferred to Atiu) in August 2002 (Fig. 2). In 2000, Birdlife International downgraded the threat ranking of kakerori from 'critically endangered' to 'endangered' (BirdLife International 2000), making kakerori one of a very few species to have had its threat ranking downgraded as a result of successful management rather than improved knowledge (Alison Stattersfield, pers. comm.).

4. Moving the kakerori project from 'recovery' to 'sustainable management' mode

In 2002, the TCA received three years of funding from the Pacific Initiative for the Environment (PIE) of the New Zealand Official Development Assistance (now New Zealand Agency for International Development) to refocus the kakerori project from 'recovery' to 'sustainable management' to enable the kakerori population to be maintained long-term at about 250 individuals on Rarotonga. A population of this size (while small by international standards) is probably sufficient to withstand normal demographic perturbations and maintain adequate genetic diversity, especially given the extreme longevity of kakerori and the evenness of reproductive output among individuals. However, single-island endemics like the kakerori are highly vulnerable to catastrophic declines or extinction resulting from major environmental disasters such as cyclones, new avian diseases (e.g. a mosquito-borne virus) or introduced predators (e.g. if the brown tree snake *Boiga irregularis* established in Rarotonga). Because of the population's vulnerability, work started to establish an 'insurance' population on Atiu through the transfer of 10 young kakerori in August 2001 and August 2002.

The 3 years of funding from PIE allowed the poisoning effort in the TCA to be experimentally reduced to establish what level of predator control would maintain the kakerori population on Rarotonga at about 250 birds. This funding also allowed the third and final transfer of ten birds to Atiu, and the outcome of the three transfers to be monitored.

The objectives of the 'sustainable management' work (carried out over three field seasons—2003/04, 2004/05 and 2005/06) were:

1. Conduct an annual pre-breeding 'roll call' and territory mapping of kakerori in the TCA.
2. Mist-net and colour-band as many kakerori as possible in the TCA to record the breeding productivity in the previous season, and record the annual survival rate.

3. Reduce the annual rat poisoning effort by replacing the single bait in each bait station fortnightly in the Turoa, Totokoitu, and Lower Avana Valleys, and around the perimeter of these three valleys in the TCA.
4. Compare the breeding success (% of successful pairs) and number of fledglings produced in those territories subject to fortnightly poisoning, with those with no rat poisoning.
5. Transfer a further 10 juvenile kakerori from the TCA to Atiu in early spring 2003.
6. Monitor the survival of kakerori on Atiu, and determine if they have bred.
7. Report results back to the Cook Islands and conservation science community.

Because five cyclones struck the southern Cook Islands in the space of 5 weeks in February/March 2005, including two ('Meena' and 'Nancy') that inflicted more damage to the TCA than any others in living memory (de Scally et al. 2006; Robertson & Saul 2006), we were forced to extend the project by two years (with funding from the Disney Wildlife Foundation, Swedish Club of 300, and the Global Environment Facility). This extension allowed us to better gauge whether the population decline noted between August 2004 and August 2006 was due to the effects and after-effects of the cyclones, or to inadequate protection from the new (reduced) poisoning regime. Because our census results are conservative, we had to wait until the completion of the August 2007 census for an accurate estimate of the true population size in August 2006, and a conservative estimate of the productivity and adult survival in 2006/07.

5. Results of the 'sustainable management' trial 2002–2007

5.1 KAKERORI CENSUS

The main census of kakerori was carried out each August, but some birds were also added to the annual totals during the course of other work each breeding season (Fig. 2).

In 2002/03, the population of kakerori on Rarotonga grew 8% from 272 birds (after the removal of 10 birds to Atiu) in August 2002 to 293 birds in August 2003, mainly due to excellent recruitment of yearlings (54 added to the population).

The following year (2003/04), the population stabilised, with a slight decline from 283 birds (after the removal of the final batch of ten youngsters to Atiu) in August 2003 to 281 birds in August 2004. A total of 55 yearlings was recruited to the population, almost balancing the somewhat higher than usual adult mortality.

Following the occurrence of five cyclones in February and March 2005, we expected that the population would have crashed; however, we found 275 birds, a small (2%) decline. Following the cyclones, vegetation on many south-facing territories, spurs and ridge-tops in the TCA was found to be severely damaged and

only sparsely populated with kakerori. However, the birds had moved from these areas and were concentrated in areas that had been more sheltered during the cyclones. Despite the cyclones damaging much of the ridge-top habitat favoured by young kakerori, 49 yearlings were recruited. The mortality rate of very old (> 20 years) and young (< 5 years) birds was much higher than the 15-year average from 1989 to 2004 (Table 1), and this contributed to the population decline observed.

The most important effects of the cyclones were not seen until the 2005/06 breeding season, when there were many starving rats (whose normal foods of fruits and berries were less available because of vegetation damage caused by the previous year's cyclones). During the August 2006 census, we saw rats during daylight hours every day, whereas in other years we would usually see just one or two rats during the whole census. Many dead rats were found before poison was laid, and rats were observed feeding on unripe fruit. These unusual observations all indicated a high rat population which was crashing due to a shortage of food. The continued reduction of canopy cover in the year following the cyclones also meant that the kakerori nests were particularly exposed to the heavy rain encountered in 2005/06. We estimated that well over 500 mm of rain fell in the TCA in November 2005, and another 800 mm fell in January/February 2006. The persistent heavy rains meant that adult kakerori could not forage effectively, so were not able to obtain enough food for their nestlings and fledglings. In August 2006, the population had fallen 8% to 254 birds, with only 31 yearlings recruited. Adult mortality (at 25%) was again much higher than the long-term average, especially in the younger cohorts and > 20 year old cohorts (Table 1).

In August 2007, following 3 years of decline, the kakerori population had started to increase again. Although the actual census total (260 birds) was only a modest increase from the 254 birds recorded the previous year, it is clear that this was a very conservative estimate, because subsequent observations added another 11 birds, bringing the minimum population to 271. At least 60 yearlings were recruited to the population, but this good productivity was partially offset by adult mortality again being higher than the long-term average, especially in the younger cohorts and in the birds aged > 20 years (Table 1).

TABLE 1. ANNUAL MORTALITY OF DIFFERENT COHORTS OF KAKERORI IN THE PERIOD 1989–2004, AND IN 2004/05, 2005/06 AND 2006/07. NOTE HIGHER MORTALITY OF 1–3-YEAR-OLD BIRDS, AND OF THE FEW >20-YEAR-OLD BIRDS, IN RECENT YEARS.

AGE	1989–2004		2004/05		2005/06		2006/07	
(YEARS)	*n*	% MORTALITY	*n*	% MORTALITY	*n*	% MORTALITY	*n*	% MORTALITY
1	156	13	27	33	25	36	6	33
2	173	13	16	25	27	19	19	37
3	160	9	15	27	15	40	22	18
4	146	14	14	21	12	17	9	22
5–9	447	11	45	13	41	20	40	13
10–14	167	13	17	18	25	28	19	11
15–19	56	7	9	11	8	0	7	14
20+	11	9	5	80	2	100	4	75
Total	**1316**	**11**	**148**	**23**	**155**	**25**	**126**	**21**

The 14%–25% mortality of banded kakerori during the five years (2002–07) of 'sustainable management' was consistently much higher than the long-term average of 9% during the 'recovery' phase (1989–2002). This increase in mortality is not entirely surprising because, as the population has expanded its range, more individuals are now living outside the managed areas and so do not receive any protection from predators. Young adults and very old birds seem to be surviving less well than in the recovery phase, perhaps as a result of difficulties securing and maintaining territories as the population density has increased.

In 2007 we introduced a new regime of 'interim poisoning' to try to reduce the mortality rate of adult kakerori and lessen the impact of rats on birds during the upcoming breeding season (starting in October). A single bait was placed in each bait station in April and again in July, with the aim of reducing the rat population and killing any feral cats which ate the poisoned rats.

5.2 MIST-NETTING AND COLOUR-BANDING

Over the five August censuses carried out from 2003 to 2007, we set mist-nets on most days, and caught (and banded) 160 kakerori (Table 2). The low numbers of birds captured in 2006 reflected the very poor productivity in 2005/06, as well as a shorter period available for mist-netting compared with other years.

These new captures, offset by losses of banded birds from 2003 to 2007, brought the total number of colour-banded individuals known to be alive on Rarotonga in August 2007 to 130, or 48% of the population. The emphasis over the next few years should be to try to band as many birds as possible and so raise the proportion of banded birds in the population to over 50% by the end of the August 2009 census, because this should improve the accuracy of subsequent population estimates.

TABLE 2. NUMBER OF NEW KAKERORI IN DIFFERENT AGE COHORTS ON RAROTONGA THAT WERE CAUGHT AND INDIVIDUALLY COLOUR-BANDED BETWEEN AUGUST 2003 AND AUGUST 2007.

YEAR	YEARLING	2-YEAR-OLD	3-YEAR-OLD	4+-YEAR OLD	TOTAL
2003	16	9	2	4	31
2004	26	10	5	7	48
2005	25	9	3	4	41
2006	6	3	0	1	10
2007	21	3	1	5	30
Total	**94**	**34**	**11**	**21**	**160**

5.3 RAT POISONING

Because we had used more effort and poison controlling predators during the 'recovery' phase of the programme than was necessary to simply 'maintain' the population of kakerori, we designed an experiment to test the effect of reducing poisoning effort. The two alternative approaches considered were:

1. Maintain weekly poisoning, but treat only about 50% of the usual area (i.e. the Turoa Valley bait line and its perimeter, with possible small extensions to the circuits to cover parts of the Lower Avana Valley and Totokoitu Valley bait lines where many kakerori bred
2. Reduce baiting frequency from weekly to fortnightly, but maintain the same four bait lines as used during most of the 'recovery' phase

Both regimes would reduce baiting effort from 4 days a week to 4 days a fortnight, but option 2 would require more track and bait station maintenance than option 1 because twice the distance would be traversed during baiting. After consultation with the local community, we decided to implement option 2 because kakerori would be actively protected on the lands of all three customary land-owning families who manage the TCA, and with a greater number of pairs receiving some protection, the genetic diversity of the population should be better maintained.

In 2002, we carried out an experiment comparing weekly poisoning in the Turoa Valley with fortnightly poisoning over the three other baiting lines. This reduced both effort and the amount of toxin used (Robertson & Saul 2004), but maintained good kakerori productivity in both the weekly- and fortnightly-baited areas. In 2003, fortnightly poisoning was extended to all four bait lines; starting, as usual, in about the second week of September and ending in late December (Christmas). This was maintained until 2006, when poisoning was started about a week earlier to try to reduce rat numbers slightly earlier, and certainly by the time breeding started in October. In 2007, a significant change was made to the baiting regime, with rounds of 'interim' poisoning introduced in April and July to try to reduce the population of breeding rats, and simultaneously provide a dose of secondary poison to any cats that may have moved into the TCA since the main baiting period (September to December).

The pattern of bait take was similar in most years of the 'sustainable management' trial (Fig. 3), and mirrored those observed during the 'recovery' project, with a very high removal rate initially, followed by a steady decline through the season until a rise towards the end of November or December. Trapping carried out during the 'recovery' project showed that this increase in bait take towards the end of the season was associated with an influx of Pacific rat (kiore, *Rattus exulans*), rather than the more harmful ship rat. However, the results from 2007 were strikingly different from this general pattern. Bait take dropped exceptionally rapidly, probably due to the 'interim' poisoning significantly reducing the breeding population of rats before the start of the usual baiting season.

The pattern of bait take during the 'sustainable management' trial also varied between the four baiting lines (Fig. 4). Bait take in the Totokoitu Valley tended to be high for the first half of the season, but we do not know why. One possibility we considered was that rats in this valley may have developed an immunity to the toxin after 15 years of exposure. To test this, we set out 30 live-capture traps in the valley for 10 nights in 2003 and caught two rats. Each rat was held in captivity

and fed a single poison bait block, along with coconut meat and water to sustain them. Within a week, both rats died of haemorrhaging typical of brodifacoum poisoning, indicating that it was unlikely that they had developed an immunity to the toxin.

The fortnightly baiting regime took 4 person days per fortnight, whereas the weekly regime carried out during the 'recovery' project took 3.5 days each week (including preparation and ordering of baits, and collation of results), an overall reduction in effort of 43%. The average amount of poison bait taken by rats each year from 2002 to 2006 was 38.9 kg (30.2–55.9 kg), compared with 52.2 kg in 2001/02, the last year of weekly 'recovery' baiting throughout the same management area. This 25% decrease in average bait take was less than the 50% decrease that might have been expected from halving the baiting frequency, because rat numbers took longer to decline with less exposure to baits. The

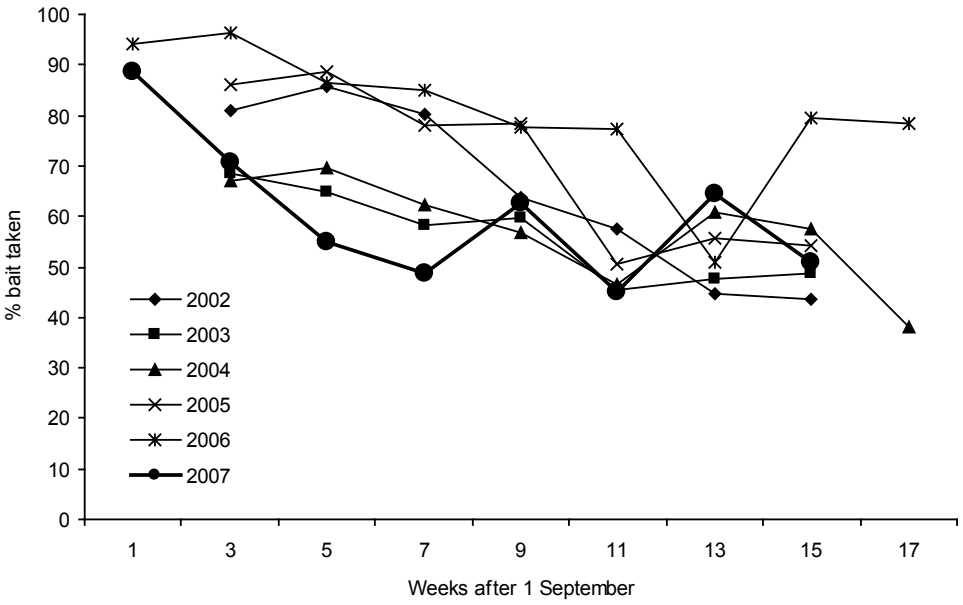

Figure 3. Fortnightly pattern of bait removal in the TCA in 2007 compared with the previous five years.

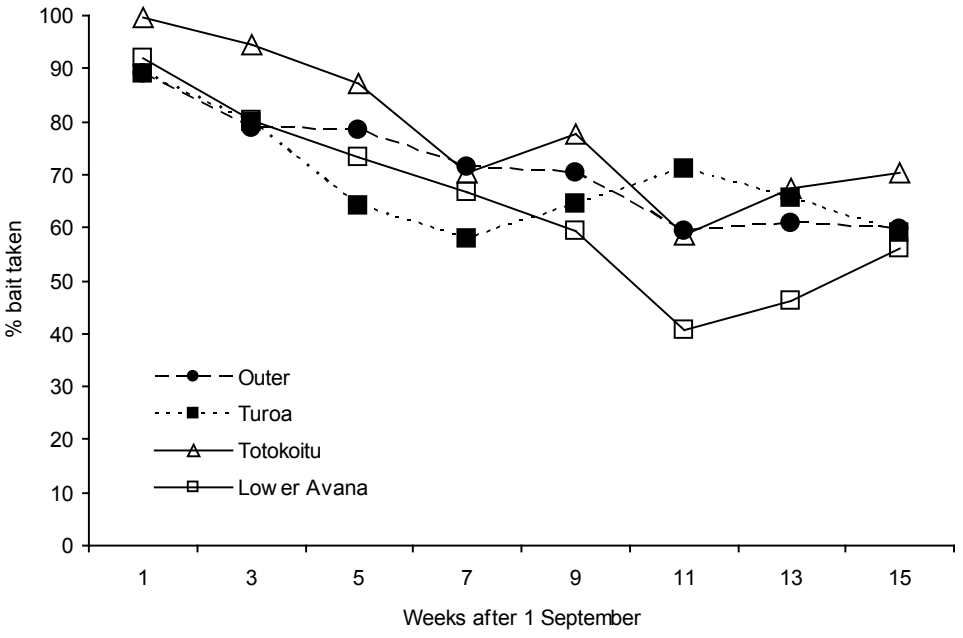

Figure 4. Average fortnightly bait removal around the perimeter of the TCA (Outer) and in the Turoa, Totokoitu and Lower Avana Valleys, from 2002 to 2007.

average amount of bait used in this new 'sustainable management' baiting regime was only 13% of the 303.5 kg used over the same geographical area during the peak year of bait use (1991), when three baits were deployed per bait station for most of the season, and bait station density was greater (Robertson et al. 1998).

The modified 'sustainable management' poisoning regime introduced in 2007, with ten complete rounds of poisoning, including the two 'interim' rounds in April and July, meant that 77 kg of bait was used that year compared with the 69.3 kg used in the nine fortnightly rounds of the previous year. However, because bait take during the normal baiting season was so much lower than normal, 5% less bait was actually eaten or removed by rats (52.8 kg c.f. 55.9 kg), so less toxin was introduced to the environment than the year before. It will take several years to determine if the modified regime, with its interim poisoning rounds, is more cost-effective than the previous fortnightly poisoning regime.

5.4 BREEDING SUCCESS

Breeding success of kakerori was monitored from 2002/03 to 2006/07 by Ed Saul, Lynda Nia, and a number of volunteers (mainly from the University of Alberta, Canada). Breeding success was moderately good throughout the TCA in both the 2002/03 and 2003/04 seasons, with a record minimum of 80 fledglings detected in the latter season (Robertson & Saul 2005). In 2004/05, fledgling surveys were effectively curtailed once the TCA had been hit by the first of five cyclones experienced in late summer, because storm damage closed all the access tracks, and fallen debris made travel off-tracks difficult and dangerous. At that stage, a minimum of 59 fledglings had been found, but the total was probably similar to the record set in the previous season (Robertson & Saul 2006).

In 2005/06, the situation was quite different, with only 22 fledglings detected during the season (Robertson & Saul 2007). Even so, this was still an underestimate of true productivity, because 31 yearlings were detected the following August. The canopy damage caused by the five cyclones in early 2005 meant that nests were more exposed to rainfall and many nests failed or fledglings died before they could be detected during periods of prolonged heavy rain in November 2005 and January/February 2006. The persistent heavy rains over this period also reduced foraging opportunities for kakerori. These factors, combined with high numbers of especially hungry rats, probably accounted for the exceptionally poor breeding success in 2005/06.

The canopy had still not fully recovered by the 2006/07 season; however, the weather was quite benign and no cyclones were experienced in the southern Cook Islands. A minimum of 51 fledglings was detected during the breeding season, and 60 yearlings were found in August 2007, and so the situation appeared to be returning to normal after the major perturbation caused by the 2005 cyclones.

Breeding success was consistently better in the poisoned areas than in the unpoisoned areas, but the data were biased in favour of finding fledglings in poisoned areas because the more accessible territories in these areas were visited more frequently than those in more distant non-poisoned areas.

5.5 ATIU TRANSFERS

Between 15 and 19 August 2003, mist nets were used to catch eight kakerori yearlings (five females and three males) and two 2-year-olds (one male and one female) in the TCA. These birds were transferred to Atiu in five batches of 1–4, and were the third and last transfer of this initial series of transfers (started in August 2001; Robertson et al. 2006). Most of the birds in this third transfer were caught in the late afternoon, held overnight in transfer boxes with fruitfly larvae as food, and flown to Atiu on a scheduled flight the following morning (although one batch of three birds was caught in the early morning and transferred the same day). During transfer of one consignment of six birds (carried in three boxes), one box containing two birds was not off-loaded from the plane at Atiu and was returned to Rarotonga. A special charter flight had to be arranged to drop the birds off 4 hours after the other birds had arrived. Eight birds were released within 20 hours of capture, and all flew off strongly when released in the vicinity of the Atiu Motel, near the centre of the 2600-ha island. The two birds that made the double trip to Atiu were released close to the airport after being held for 8 hours and 22 hours respectively. The latter bird was slow to fly off, but did so when a pair of kakerori appeared nearby. None of the 30 birds released on Atiu during the three transfers has reappeared on Rarotonga.

5.6 ATIU MONITORING

George Matearíki has followed the progress of kakerori on Atiu since the first release of ten birds in August 2001, and he has also investigated records received from the local community. Ed Saul, with recent assistance from Lynda Nia, has made annual or bi-annual visits to Atiu to check distribution, breeding success, colour-band combinations, and to solicit extra records by playing taped kakerori calls. Various ornithologists visiting Atiu have also supplied us with records of banded birds, or of birds in new locations. In October 2004, the staff and pupils of Enuamanu School on Atiu helped to survey inland valleys of the northern part of the island, and further surveys have now covered most of the inland part of the island. Much suitable habitat around the outside of the 2600-ha island has not been searched, because the coastal ring of makatea (raised coral reef) is almost impossible to traverse, and there are few roads or foot tracks in these extremely rugged areas.

Two pairs from the first release in August 2001 each raised two fledglings in the 2002/03 season, thus proving that conditions on Atiu were suitable for kakerori breeding (Robertson et al. 2006). Of particular interest was the observation that nests were constructed from a variety of plant material and dead mosses, and lined with needles of *Casuarina* trees. The *Aerobryopsis* moss, which is the main nest material on Rarotonga, is absent from Atiu, so kakerori nests on Atiu were brown rather than the usual distinctive green of Rarotonga nests. This indication of adaptability in behaviour augured well for the future of kakerori on Atiu.

In subsequent years, successful breeding has been recorded in a variety of habitats (Robertson et al. 2006), including many quite different from those used on Rarotonga (e.g. makatea forest, coastal forest, and secondary forest).

In makatea forest, kakerori used *Neckeropsti*, another air-plant moss for nest construction, so nests were green, like those on Rarotonga. By 2005/06, some of the successful pairs included one island-bred bird, and in 2006/07, the first island-bred pair raised their own fledglings.

In 2006/07, a minimum of 43 adult kakerori were alive on Atiu (Fig. 5): 2 trios, 15 pairs and 7 singletons, including at least 18 of the 30 colour-banded birds transferred from Rarotonga between 2001 and 2003. In addition, at least 11 fledglings were known to have been raised during the season, but the total is likely to have been higher than this because several pairs were not monitored soon enough after breeding to know whether or not they produced and fledged chicks.

The good survival of released birds, together with the good productivity of pairs in diverse habitats, indicates that this new 'insurance' population is becoming well established, despite having to live with kiore and cats (but not, importantly, with ship rats).

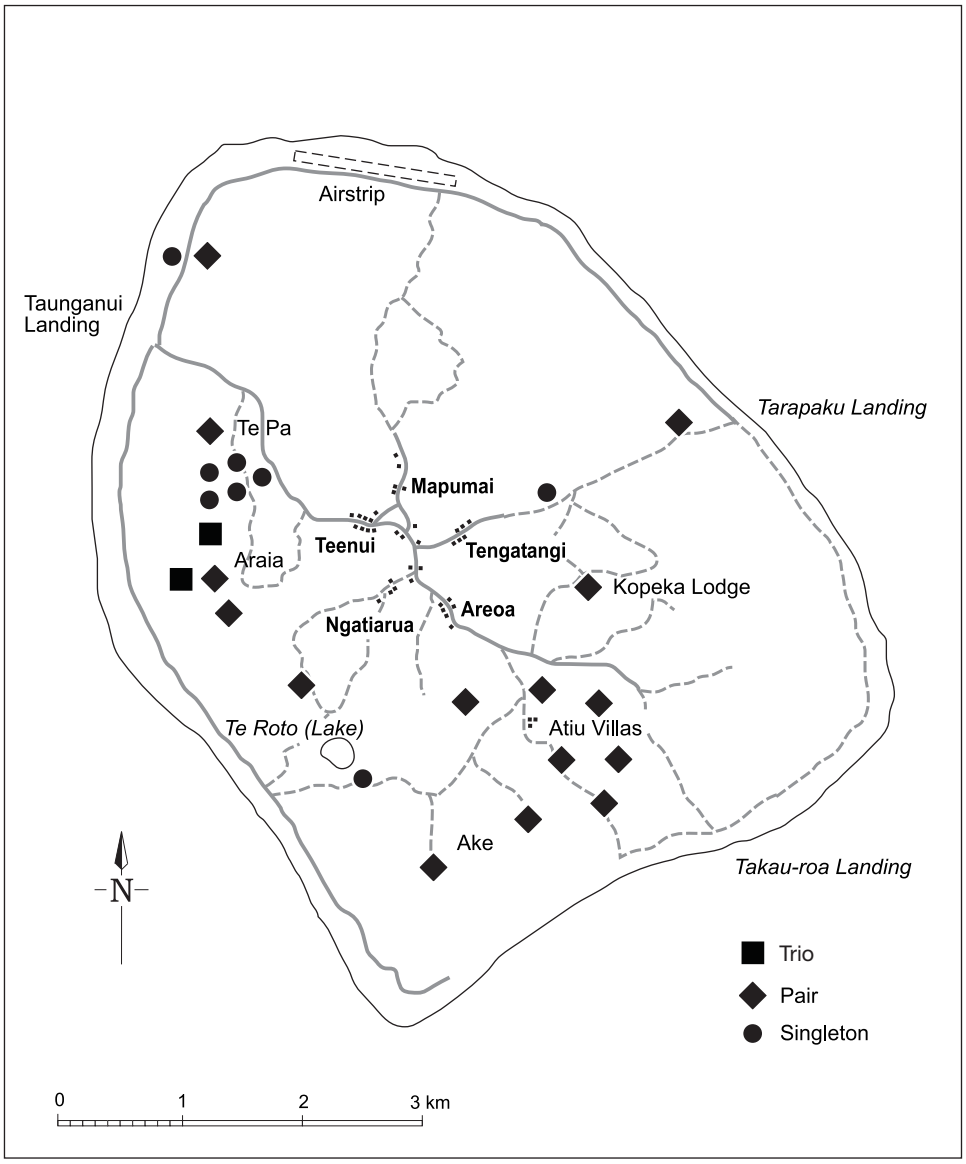

Figure 5. Map of Atiu showing the locations of the 43 adult kakerori seen, reported, or deduced from later sightings, in 2006/07.

5.7 ADVOCACY

Through many television and newspaper articles, the TCA Project has maintained a high profile in the Cook Islands. Numerous school groups have been guided into the TCA as part of their science studies. Between 500 and 1000 overseas ecotourists visit the TCA annually on guided walks, and most manage to see kakerori during their tour.

On Atiu, George Matearíki (a graduate of the TCA's ecotourism workshop) now runs ecotours which include a visit to see kakerori. The Enuamanu School teachers and pupils have also been involved in some of the survey work.

6. Long-term maintenance of the kakerori population

The 2002/03 season marked a major turning point in the kakerori recovery programme, from one aimed principally at 'recovery' to one aimed at 'sustainable management'. A key element of this shift was the experimental reduction in management effort on Rarotonga to find a level which maintains the kakerori population at about 250 individuals, but which is also both physically and economically sustainable for the TCA Project to run in the long term. The reduction in the frequency of replenishing poison baits has reduced the effort and the amount of toxin used. Despite catastrophic cyclones hitting Rarotonga in 2005, and after-effects felt in the 2005/06 breeding season, the kakerori population has remained above 250 birds. We therefore believe that fortnightly poisoning will prove to be an effective, cheaper and less toxin-intensive method of protecting kakerori than weekly poisoning. The introduction of two rounds of 'interim' poisoning in April and July 2007, to try to reduce the rat and cat population between breeding seasons, appears to have been beneficial and reduced bait use during the following breeding season. With this 'modified' fortnightly management regime in place, we believe that outcome monitoring can be greatly reduced and should only need to be increased if the kakerori population is affected by some catastrophic event, or if a change in management is planned.

The second element in the move to 'sustainable management' of kakerori was the establishment of an 'insurance' population on Atiu. The main transfers of birds have now been completed, and the population seems to have established successfully. While there appears to be no immediate need to transfer more kakerori to Atiu, conservation genetics theory (for example, Allendorf & Luikart 2007) suggests that to maintain genetic diversity in this second population, one new founder should be introduced from Rarotonga every kakerori generation, i.e. about every 7 years—the average age of breeding females. Outcome monitoring on Atiu can also be reduced after the 2007/08 season, especially if the identity of several unknown birds can be determined.

6.1 RECOMMENDED MANAGEMENT ACTIONS FOR MAINTAINING A VIABLE POPULATION OF KAKERORI IN THE COOK ISLANDS

These recommendations apply particularly to the Takitumu Conservation Area (TCA) Project on Rarotonga, for their planning and for future funding applications:

- Maintain the existing management programme in the TCA by poisoning rats fortnightly from early September until late December (Christmas), and record fortnightly bait take from the 428 bait stations used in recent years.
- Carry out two rounds of 'interim' poisoning in March/April and June/July each year.
- Record the number of fledglings seen in as many territories as possible (in poisoned and unpoisoned areas) during each breeding season and until March/April.
- Mist-net and individually colour-band as many birds as possible during August each year.
- Every second year (starting in 2009), carry out a detailed population census by mapping the locations of banded and unbanded kakerori of different age cohorts. At a 2-yearly interval, it will be possible to identify yearlings, 2-year-olds and 3-year-olds from their bill colour and/or plumage, and so relate years of good and bad recruitment to weather and/or rat abundance (as measured by annual bait take patterns).
- In 2009 or 2010, transfer two yearling kakerori (one male and one female) to Atiu, and repeat this every 7 years.
- Review progress every 2 years after the completion of the population census. Aim to increase management effort (e.g. introduce weekly poisoning for all or part of the season or management area) if the kakerori population has fallen below 250 birds, and reduce effort (e.g. remove one of the two rounds of 'interim' poisoning) if the population exceeds 300 birds.
- Commission a special population census if an ecological disaster strikes Rarotonga (e.g. a tropical cyclone of magnitude similar to or greater than those of 2005), or a new predator is confirmed on the island.
- Maintain a watch on the kakerori population on Atiu, and maintain records of locations of birds seen or reported. Carry out a survey every three years to ensure that a minimum of 30 adult birds is present on the island.
- Continue guided visits for schools to the TCA, and television and newspaper coverage of activities, successes, and challenges as part of an ongoing advocacy programme to educate Cook Islanders about their unique natural heritage.
- Continue to report results of the programme to the international conservation and science communities, and so maintain the mana of the project as a leading example of a community-led conservation project in a regional and international context.
- Maintain ecotours to the TCA as the primary means of raising revenue for the annual management programme (rat poison, fledgling monitoring and mist-netting/colour-banding).

- If necessary, seek additional funding for the two-yearly detailed population census and transfers of small numbers of birds to Atiu.
- Maintain and (wherever possible) increase the training of local Cook Islanders in implementing the annual rat poisoning, fledgling searches, mist-netting/ colour-banding programmes, and two-yearly population census on Rarotonga, and monitoring of the Atiu population.
- Continue to press for better legal protection of native wildlife in the Cook Islands.

7. Acknowledgements

Funding from the Pacific Initiative for the Environment of the New Zealand Agency of International Development has helped us to monitor kakerori numbers on Rarotonga, monitor the breeding outcomes in territories under the different management regimes, carry out the third and final transfer of birds to Atiu, and monitor their numbers on Atiu. With support from Taporoporoanga Ipukarea Society and BirdLife International, we received extra financial assistance from Disney Wildlife Conservation Fund and Club 300 (Sweden) for work in 2005/06, and from the Global Environment Fund in 2006/07, especially after five cyclones caused so much damage in the TCA in 2005, and the project was extended to determine if the kakerori population had remained above the minimum level of 250 birds.

The TCA Project contributed substantially to the 'sustainable management' study by covering vehicle running costs, poison bait supply, and some of George Matearikiʼs expenses on Atiu. They also provided accommodation and safety equipment for volunteers helping with the field programme on Rarotonga.

The Department of Conservation, New Zealand, allowed Hugh Robertson to take special leave on pay to assist with the field project each year until 2007.

Many ornithologists and other volunteers helped with the conservation programme on Rarotonga. We especially thank Derek & Ros Batcheler (Ornithological Society of New Zealand (OSNZ)), Phil Battley (OSNZ), Mathew Chan (Victoria University, Wellington, NZ), Diana Dombroski (OSNZ), Sue Moore (OSNZ), and Mary & Ralph Powlesland (OSNZ) for help with mist-netting, colour-banding and the annual censuses. Jasmine Braidwood (NZ Forest & Bird), Lynette Dagenais (University of Alberta, Canada), Amy Forsyth (University of Alberta), Melanie Holub (University of Wisconsin, USA), Adam Isaacs (University of Colorado, USA), Barbara Maile (University of Alberta), Paul Jasche (University of Alberta), Lynsay Mozak (University of Alberta), and Annette Potvin (University of Alberta) provided invaluable field assistance with rat-poisoning, monitoring nesting attempts, and fledgling searches.

On Atiu, Roger and Kura Malcolm of Atiu Villas assisted with the transfers and release of birds, and made us welcome at their establishment. Matt Burt, Rose Collen, Diana Dombroski, Ian Flux, Helen Gummer, Lindsay Milne, Ralph & Mary

Powlesland and Eric vanderWerf reported their sightings of kakerori. Euan Smith kindly arranged for Air Rarotonga to carry the kakerori to Atiu free-of-charge and provided many free return flights for people to monitor the birds afterwards.

Chris Edkins drew the maps, and Lynette Clelland, Ralph Powlesland, Greg Sherley and an anonymous referee improved drafts of this report.

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