Takitumu Conservation Area Management Plan 2020–2030

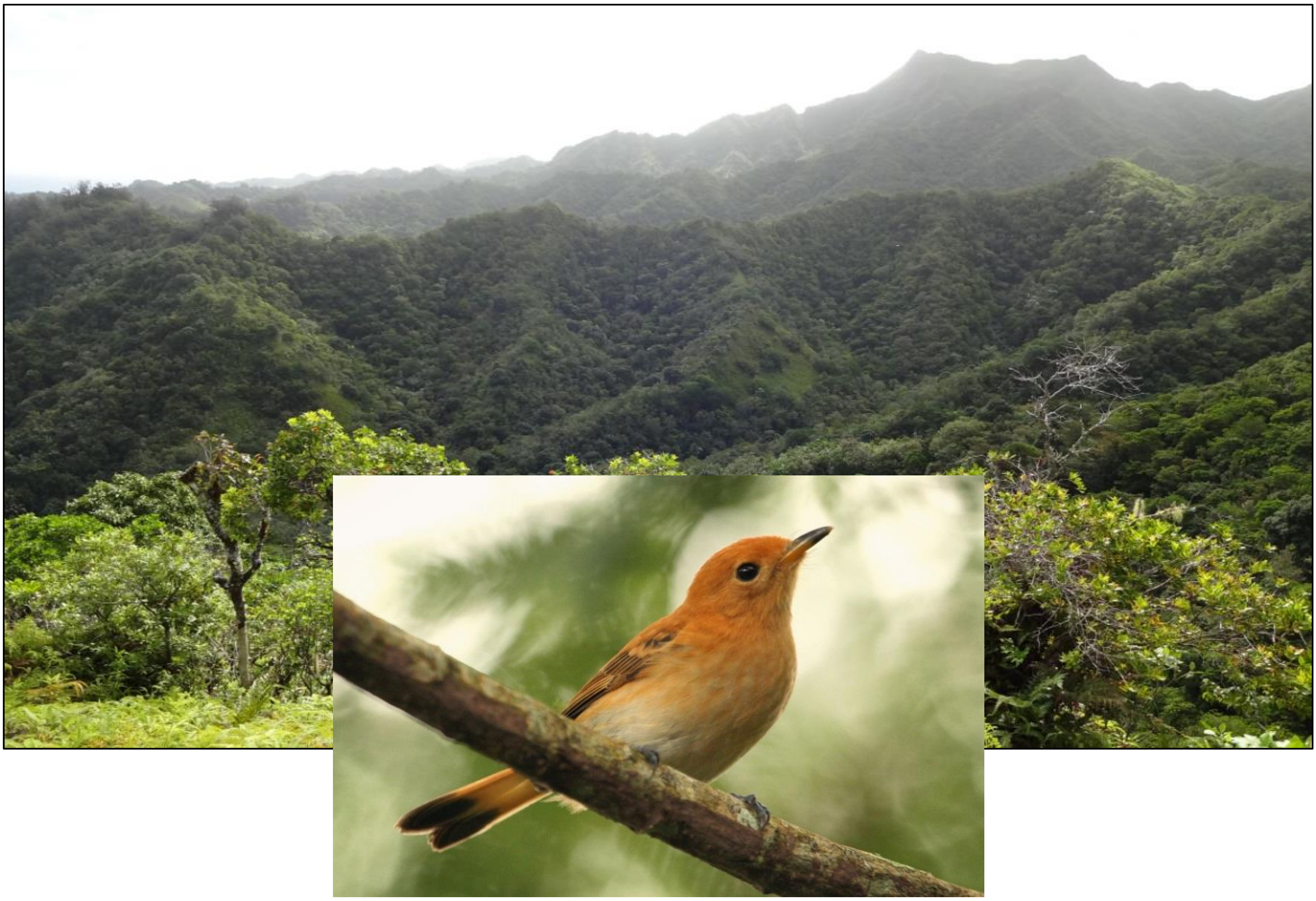

Photo: Kate Beer

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Abstract

The Takitumu Conservation Area (TCA) is a 155-ha area of forested lowland hills of southern Rarotonga, Cook Islands. It was informally protected by three landowning families in 1996, primarily to protect the small endemic forest bird, the kākerōri/ Rarotonga flycatcher (*Pomarea dimidiata*), that was once confined to this site.

In 1989, there were just 29 of the critically endangered kākerōri left in the world, and they were rapidly heading towards extinction unless predation by the introduced ship rat (*Rattus rattus*) could be reduced. An annual programme of rat control, using poison in bait stations, has run for 31 years, and this has led to the kākerōri population in and around the TCA increasing to at least 471 birds in 2017. Translocations of a total of 40 young kākerōri to form an 'insurance' population on ship rat-free Ātiu has been successful, with a minimum population of 150 birds recorded in 2017, bringing the global total to well over 600 birds, or over 20 times the number of kākerōri alive in 1989.

This plan for the next 10 years of management of the TCA recommends, among other things, to:

- Maintain the existing rat and (through secondary poisoning) feral cat poisoning programme that has been so successful, with options to fine-tune the programme to reduce labour and poison costs, to potentially use self-resetting traps, to expand the area protected and, ultimately, to consider whether the Cook Islands could be made and kept rodent-free.
- Continue to monitor the demography of kākerōri by catching and marking birds with a unique combination of coloured leg bands, and then doing a 2- or 3-yearly census by doing a "roll-call" of banded birds and mapping their territories.
- Respond quickly to threats to nature in the TCA, such as roading or housing developments, feral animal incursions, biosecurity, cyclones and weed encroachment.
- Continue to monitor the kākerōri population on Ātiu at least 3-yearly, and periodically add new founders to maintain genetic diversity of the 'insurance' population.
- Improve knowledge of the benefits that other native wildlife receives from the rat and feral cat control programme.
- Improve the educational resources about the TCA by updating brochures, booklets, photomontage posters and display panels at a renovated TCA office and/or TCA shelter.
- Secure the governance of the TCA through the landowners forming a trust as a legal entity to seek and manage funds from environmental donors.
- Carry out urgent succession planning to ensure continuity in staffing and in volunteer support for managing the TCA, doing the rat poisoning, doing the banding and census work, and running ecotours and school visits. The global Covid-19 pandemic will have a huge impact on tourism and employment in the Cook Islands.
- Concentrate on providing a high-quality natural history experience for Cook Islanders, especially for school groups.
- Initially target the niche birder/ naturalist market when international tourism resumes following the Covid-19 pandemic.

The strength of the TCA is the unique story that can be told about the remarkable recovery of the kākerōri, an endemic and endearing bird that was on the brink of extinction 30 years ago. This is one of the true success stories in Pacific conservation, and one that the TCA landowners can be justifiably proud of – meitaki ma'ata.

1. Context

This management plan for the Takitumu Conservation Area (TCA) was commissioned by the Cook Island National Environment Service as part of its contribution to the Cook Islands Ridge to Reef project, funded by the Global Environment Facility (GEF). The TCA is a 155-ha area of forest in southern Rarotonga (Figure 1) that was informally protected by three landowning families in 1996, primarily to protect the endemic kākerōri/ Rarotonga flycatcher (*Pomarea dimidiata*), one of the most threatened birds in the world.

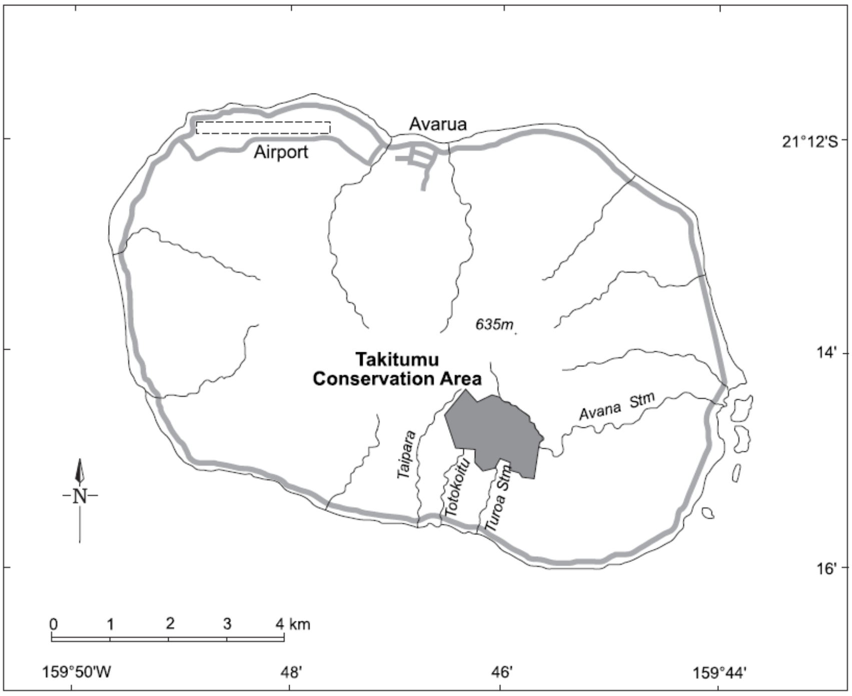

Figure 1: Map of Rarotonga showing the location of the Takitumu Conservation Area.

The Cook Islands has been a Party to the Convention on Biological Diversity since 1993 and reflects its national biodiversity values in its five-year *Te Kaveinga Nui* – National Sustainable Development Plan. These values are articulated into actions in its National Biodiversity Strategy and Action Plan and implemented through various projects, such as the Cook Islands GEF Ridge to Reef Project. The Environment Act 2003 is the primary legislation for terrestrial species conservation and management on Rarotonga, with draft policy and regulations on Access and Benefit Sharing and Biodiversity Conservation awaiting further action.

Funded by the GEF, with management oversight provided by United Nations Development Programme, the Cook Islands Ridge to Reef project looks to improve livelihoods and opportunities of communities through the integrated management of environmental resources across four key sectors, those being; environmental management, marine resource management, agriculture development and tourism growth. The Takitumu Conservation Area is identified as a primary recipient for capacity building support for ecologically sustainable management plan development, rare species management, resource provision for improved visitor opportunities, and information outreach and awareness.

2. Kākerōri conservation history

2.1 *Kākerōri conservation history – the decline history to 1987*

In the mid-1800s, kākerōri were reported to be common throughout Rarotonga, but following the accidental introduction of ship rats (*Rattus rattus*) they had become very scarce by the 1880s, and were thought to have become extinct soon after some museum specimens were collected in the early 1900s (Robertson *et al*. 1994).

In the 1970s, a small population was rediscovered in the rugged lowland hills of the island. David Todd found 21 birds in 1983 and estimated that there were 35–50 birds (David Todd, unpubl. data). In June 1984, Rod Hay and Gerald McCormack caught and colour-banded eight kākerōri near the head of the Tōtoko'itu Valley.

A thorough search of the Tōtoko'itu, Tūroa, Upper Avanā Basin, Lower Avanā Basin, and nearby valleys, revealed a total of 38 birds in 1987 (Robertson *et al.* 1994). Subsequent annual censuses identified 36 birds in 1988 and then only 29 in 1989, thus confirming that the conservation status of kākerōri was 'critically endangered' (Collar *et al*. 1994). At an average rate of population decline of 12% per year, a population viability analysis showed that there was a 50% chance that kākerōri would be functionally extinct (just one bird remaining) by 1998, and a 90% chance by 2002 (Hugh Robertson, unpubl. data). In 1989, the kākerōri was one of the 10 rarest bird species in the world, and in very urgent need of conservation management (Robertson *et al*. 1994). The ecology of the kākerōri is described briefly in Appendix 1.

2.2 *Beginning of management: the understanding and recovery phase (1987-2001) and establishing the Takitumu Conservation Area (TCA) in 1996*

As a result of a study between September 1987 and January 1988, Rod Hay and Hugh Robertson identified that ship rats (*Rattus rattus*) were the main predators at nests, and cats (*Felis catus*) were likely predators of adults and recently fledged juveniles (Hay & Robertson 1988). They recommended an experimental recovery programme targeting these predators, supported by scientific study aimed at assessing the effectiveness of this work.

The original goal of the Kākerōri Recovery Plan (Hay & Robertson 1988) was to increase the population to a minimum of 50 birds in order to move the kākerōri out of BirdLife's list of critically endangered birds. More specific objectives for the recovery phase were to:

1. Monitor, on an annual basis, the dynamics of the kākerōri 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 kākerōri population by protecting nests, providing supplementary food and, as a last resort, translocation or captive breeding.

4. Describe the habitats used by kākerōri, and determine the relationship between habitat features and the distribution of kākerōri.

5. Develop and implement a programme of public education, awareness and participation in a kākerōri conservation programme.

6. Encourage the protection of kākerōri by creating a suitable reserve and developing appropriate national and international policies regarding the scientific collection or trade in kākerōri, and the importation of wildlife (and, hence, potential predators, competitors, and diseases) into the Cook Islands.

In September 1989, an experimental programme of rat poisoning and nest protection started in about 15 ha of the upper Tōtoko'itu catchment, to protect seven of the 13 breeding pairs of kākerōri at the time. The breeding success there was much better than in the untreated areas, and so the area under protection was gradually increased by including the Tūroa Valley in 1990, the Lower Avanā Basin in 1991, and the Upper Avanā Basin in 1992, but this final area was dropped after one year because it was too onerous for one person to do on top of the other three valleys. Since 1993, rats have been poisoned between 1 September and Christmas each year in most of the TCA (Figure 2), and it is believed that most resident feral cats have died from secondary poisoning as a result of eating poisoned rats (Robertson *et al.* 1998).

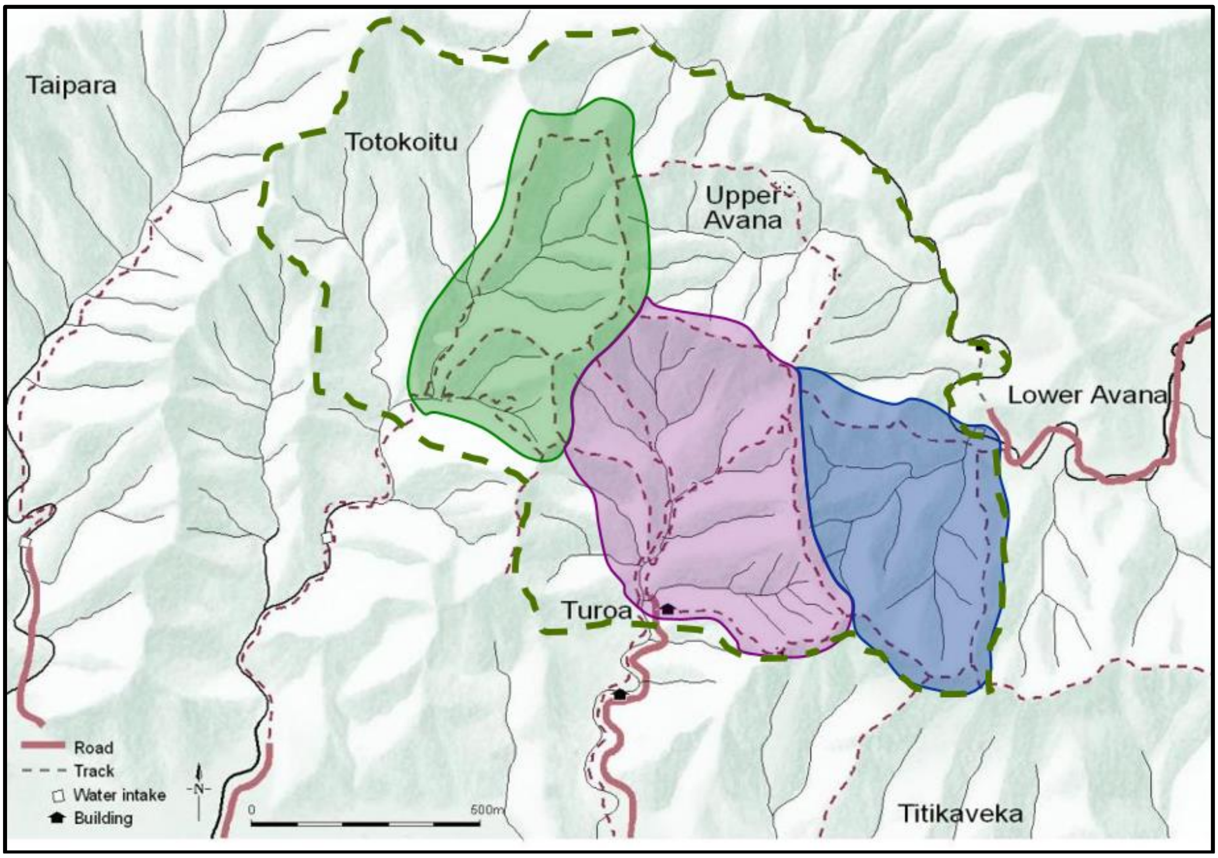

Figure 2: Map of the TCA (dashed green line) showing main tracks and the progression of rat trapping effort from the upper Tōtoko'itu (green) in 1989, to the Tūroa (purple) in 1990, and then to the Lower Avanā Basin (blue) in 1991. The Upper Avanā Basin was poisoned in 1992 only. The coloured sections have been poisoned every year since 1992.

The effectiveness of predator control was measured by recording annual breeding productivity in protected and unprotected areas (Robertson *et al*. 1998; Saul *et al*. 1998), by recording the annual survivorship of individually colour-banded kākerōri, and by undertaking an annual pre-breeding census in August/early September.

The census is made easier by the adult birds generally remaining in the same territory year after year (Saul *et al.* 1998), and the progressive changes in colour of kākerōri during their first 4 years of life (Robertson *et al.* 1993) improve estimates of the identity of unbanded birds. During this 'recovery' phase, the population of kākerōri increased at an average rate of 20% per year, from 29 birds (13 pairs) in August 1989 (Figure 3) to 255 birds (98 pairs) in August 2001 (Figure 4).

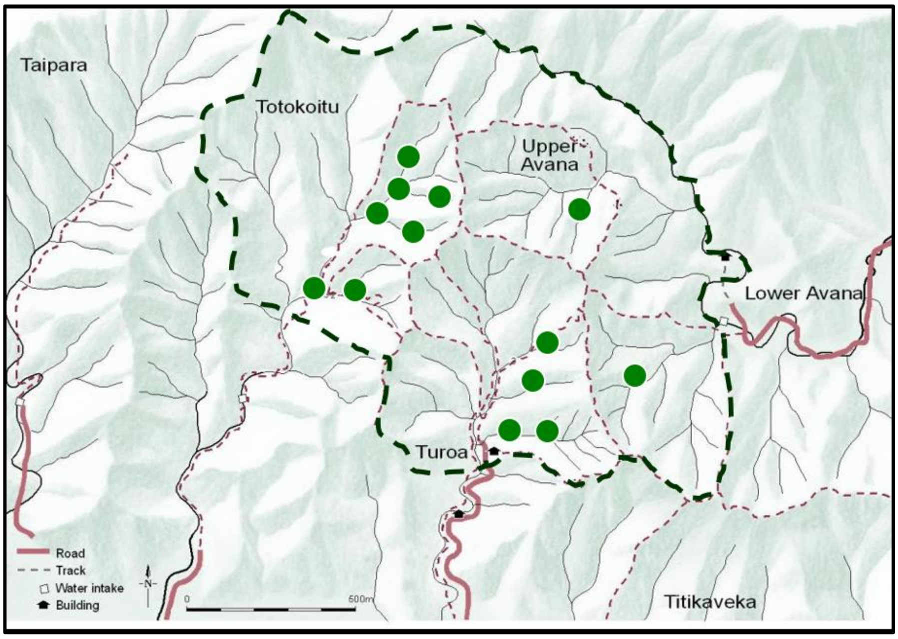

Figure 3: Map of the TCA showing the distribution of the 13 pairs of kākerōri in 1989.

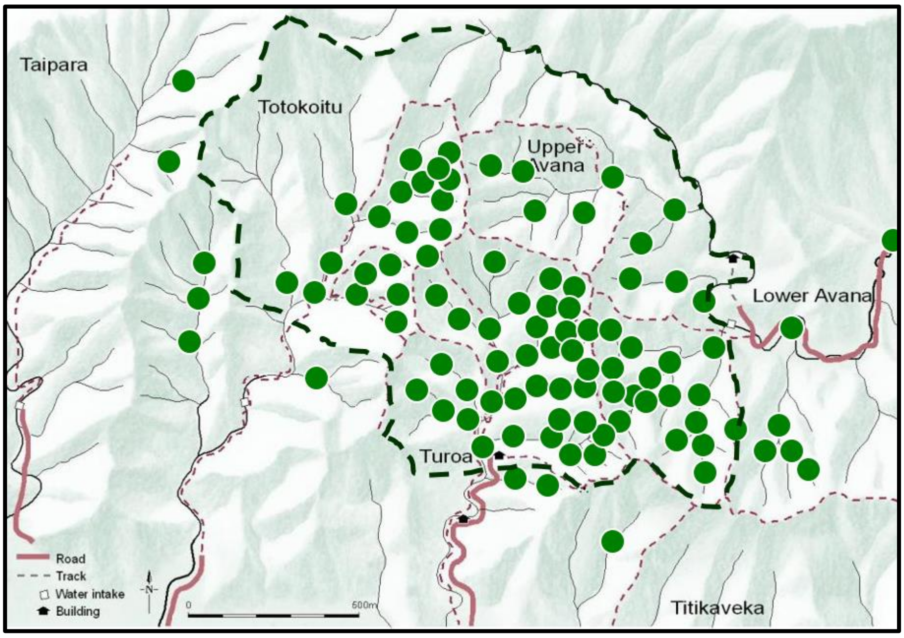

Figure 4: Map of the TCA showing the distribution of the 98 pairs of kākerōri in 2001.

In 2000, BirdLife International downgraded the threat ranking of kākerōri from 'critically endangered' to 'endangered' (Stattersfield *et al.* 2000), one of a very few species to have been downgraded as a result of conservation management rather than improved knowledge (Alison Stattersfield, BirdLife International, *pers. comm.* 2002).

The concept of creating a "Kākerōri Nature Reserve" in the current TCA site was first mooted by Gerald McCormack in July 1988 when he was Director of the Cook Islands Conservation Service. Throughout 1995, as part of the South Pacific Biodiversity Conservation Programme administered by SPREP (Secretariat for the Pacific Regional Environment Programme), the Cook Islands National Environment Service (the government agency responsible for environment that evolved from the Cook Islands Conservation Service) discussed with the traditional leaders and landowners of the kākerōri's core breeding area the idea of creating a Conservation Area on their land. At first, the landowners were not supportive because they were concerned that if they agreed to designate their land as a Conservation Area, that would become its legal status and their continued ownership would be threatened. During consultations, it was emphasized that the designation as a Conservation Area would not involve legal ownership but only a verbal agreement and the owners would still have control of their land. In time, this assurance was accepted by the landowners after stringent debate.

In 1996 the three valleys that make up the core kākerōri area were declared as the Takitumu Conservation Area (TCA) by the three customary landowning tribes (Kainuku, Karika and Manavaroa). Although the conservation area agreement was informal, the three landowning families have respected and grown the conservation values of their land over a nearly 25-year period.

With financial assistance from the South Pacific Biodiversity Conservation Programme (SPBCP), the TCA was set up with the aim of conserving biodiversity for the benefit of present and future generations of Cook Islanders and others. In the central Tūroa Valley, the former road access to an Outward Bound campsite was re-instated, walking tracks were constructed to a standard suitable for tourists to use, and a visitor shelter with toilet facilities was built. In other parts of the TCA, tracks for servicing poison bait stations were improved and safety ropes added to steep sections, and vegetation and faunal surveys were completed.

Thus, the 155–ha TCA in south-eastern Rarotongan forest protected the home of most kākerōri (Figure 1). At the same time, it aimed to generate some income for the landowners through the development of a sustainable ecotourism venture (Tiraa & Wilmott, 2001). The TCA is managed by the Takitumu Conservation Area Co-ordinating Committee which comprises representatives of the three customary land-owning families plus TCA workers on an *ad hoc* basis. In 1996, the management of the recovery programme was passed to the committee. They have continued to oversee management of kākerōri through the work of Ian Karika even though the SPBCP programme finished in 2001.

The original goal of increasing the kākerōri population to a minimum of 50 birds had been achieved by 1992, and most of the other original objectives had also been achieved by 2000 (Table 1).

Table 1: Success of objectives developed for the recovery phase of kākerōri, 1988-2000 (Hay & Robertson 1988).

Objective	Achievement of objective
Monitor, on an annual basis, the dynamics of the kākerōri population on Rarotonga.	Achieved. Annual monitoring occurred until 2007 when the population reached a level where less regular monitoring (biennial) was warranted. After 2017, monitoring was reduced to every 3 years.
Research, develop and implement an effective predator (rat and cat) control programme.	Achieved. Rat and cat control by using poison (brodifacoum) baits in bait stations from September to Christmas each year since 1989 allowed recovery.
Research, develop and implement a programme of managing the kākerōri population by protecting nests, providing supplementary food and, as a last resort, translocation or captive breeding.	Achieved: pest control very effective. The labour-intensive job of finding nests and then banding nesting trees had been discontinued. Translocation partially achieved; project planning and site assessment had begun to establish a second population elsewhere in the southern Cook Islands. Supplementary food was never required.
Describe the habitats used by kākerōri and determine the relationship between habitat features and the distribution of kākerōri.	Achieved: Their use of habitat was described in a Massey University MSc thesis (Sanders 1993) and scientific paper (Sanders *et al*. 1995), and the use of different tree species as nest sites was related to their abundance in the TCA in a scientific paper (Saul *et al*. 1998).
Develop and implement a programme of public education, awareness and participation in the kākerōri conservation programme.	Achieved: McCormack & Kunzle (1990) produced an illustrated booklet for schools and the general public on the kākerōri, and they also featured on postage stamps. By 2000, the kākerōri was much better known among Cook Islanders compared with other endemic landbirds (Ana Tiraa, unpubl. data), the kākerōri has become the *de facto* 'bird of Rarotonga'. School groups have visited the TCA on a regular basis.

Encourage the protection of kākerōri by creating a suitable reserve and… developing appropriate national and international policies regarding the scientific collection or trade in kākerōri, and the importation of wildlife (and, hence, potential predators, competitors, and diseases) into the Cook Islands	Achieved. TCA established in 1996 Achieved. In the decade before 1988, several kākerōri were collected for overseas museum collections in expectation that they would soon become extinct, but no kākerōri were known to have been collected since 1988. Tight biosecurity policies/legislation remained largely unachieved until the passing of the Cook Islands Biosecurity Act in 2008. The Cook Islands National Environment Service is currently reviewing the 2003 Environment Act, which includes a dedicated and more stringent section on Biodiversity, as well as developing a strengthened Protected Areas Management policy, both of which will further support the TCA and the kākerōri from take, trade and biosecurity risks.

2.3 The sustainable management phase (2001- present)

Since 2001, the aims during the sustainable management phase has been two-fold: firstly, to establish an 'insurance' population of kākerōri at a different site, and secondly, to experimentally reduce the rat poisoning effort in the TCA to a level where recruitment of kākerōri more - or- less balances annual mortality and so maintains the population at 250–300 birds (Robertson & Saul 2004).

2.3.1 Translocations

Robertson *et al*. (2006) provided a detailed review of the planning and work that went into the translocation of kākerōri from the TCA to Ātiu.

The TCA landowners strongly supported the concept of establishing of a second, 'insurance' population of kākerōri, in case catastrophe struck the local population on Rarotonga. It was agreed that establishing a second population on Rarotonga would not provide adequate protection for the species because it was likely that anything (e.g., cyclones, disease, a new predator) that threatened kākerōri in the TCA would also threaten any other population established on Rarotonga. The TCA landowners did not want to translocate kākerōri outside of the Cook Islands, and so it was agreed to assess islands in the southern Cook Islands first, and if nothing was deemed suitable, then islands in the northern group would be assessed.

From phylogenetic research on the *Pomarea* genus, it appeared that a *Pomarea* species inhabited the Cook Islands before the appearance of Rarotonga about 2 million years ago, and so must have inhabited some of the older islands (such as Aitutaki, Ātiu and Mangaia) in the southern group (Cibois *et a*l. 2004, Robertson *et al*. 2006).

Ed Saul carried out a detailed assessment of the suitability of islands in the southern Cooks, initially as a desktop exercise. Islands were scored based on area of suitable habitat, presence of ship rats and cats, presence of competitors or avian predators, transport links to carry out a rapid transfer of birds. Following this initial assessment, Ātiu and Aitutaki stood out as preferred options given the apparent absence of ship rats from these large and partly forested islands. Ed Saul then visited the islands to do more in-depth investigation of habitat suitability and to carry out rat-trapping to see if he could detect any ship rats. Meanwhile, Ian Karika and other members of the TCA committee approached the Island Councils of the two front-running islands to see whether they supported the translocation of kākerōri to their islands. The Ātiu Island Council was very enthusiastic about the proposal, and Ed Saul found no evidence of ship rats and assessed that although different habitats were present compared with Rarotonga, Ātiu had a variety of habitats that kākerōri were expected to do well in. There seemed little likelihood that kākerōri would compete with any native bird species on Ātiu because the leaf-gleaning niche they fill was vacant. Disease screenings were carried out on Rarotonga in 2000 to make sure that kākerōri did not harbour any diseases that might infect birds on Ātiu.

The only concerns were that Ātiu did not have the *Aerobryopsis longissima* moss that kākerōri use to build their nests with on Rarotonga, and that ngōtare/ chattering kingfisher (*Todiramphus tutus*) could be an egg/chick predator. Subsequently, the kākerōri found another usable moss in the makatea (raised coral area) to build into nests.

In August 2001, ten young kākerōri (1- and 2-year old) were transferred from the TCA to Ātiu, and another ten young birds were transferred each year for the next two years, making a total of 30 initial founders (Robertson *et al*. 2006). The survival and, to a lesser extent, the breeding of kākerōri has been monitored on Ātiu since the initial release. First breeding was detected in the 2002/03 breeding season, and subsequent biennial surveys by Ed Saul and Lynda Nia, with on the ground intelligence from George Mateariki, has shown that the population increased steadily to c.150 birds in 2012. However, with the removal of the common myna (*Acridotheres tristis*) from the island by 2016 in a Cook Islands Natural Heritage Trust project, ngōtare/ chattering kingfisher increased in abundance and began to prey on kākerōri nests and apparently extinguished one node of three breeding pairs (Ed Saul, pers. comm.). A rapid survey in September 2018 found a minimum of 123 birds, but this was considered to be an underestimate because only seven yearlings were found, and it seemed likely that the majority of the 2017/18 cohort were living in inaccessible makatea habitats (Tui Wright, pers. comm), unless the level of ngōtare/ chattering kingfisher predation had greatly reduced the productivity of kākerōri.

The lack of banding effort on Ātiu means that apart from having all the founders individually colour-banded, population estimates have relied on mapping birds in known territories of different age-related plumages. The inaccessible nature of parts of Ātiu has also meant that kākerōri population estimates are conservative, and so apart from the possibility of increasing ngōtare/ chattering kingfisher predation, there is no reason to suspect that the population has declined between 2012 and 2018.

Following an assessment of the genetic diversity of the TCA population of kākerōri using microsatellite and mitochondrial DNA markers (Chan *et al*. 2008, Chan *et al*. 2011), it was recommended that a further 10 young birds be transferred to Ātiu so that the population better represents the genetic diversity of the TCA population, and to prevent genetic drift in the Ātiu population (Mathew Chan, pers. comm.). A further 10 young kākerōri were successfully transferred to Ātiu in August 2011.

2.3.2 Experimental reduction in the rat poisoning effort in the TCA

A population of 250–300 birds on Rarotonga, while small by international standards, is probably sufficiently large to withstand normal demographic perturbations and to maintain adequate genetic diversity, given that the population passed through a bottleneck of just 13 females alive in 1989. Nevertheless, this population, occupying less than 200 ha on one island, remained at significant risk of substantial decline or extirpation from a major catastrophic event. The overall aims of the sustainable management phase on Rarotonga from 2001 to the present day (Robertson & Saul 2006) have been to:

1. Maintaining annual rat-poisoning regimes in the Tūroa, Tōtoko'itu and Lower Avanā Valleys.
2. Compare the breeding success of kākerōri breeding pairs in territories with and without rat-control.
3. Reporting results back to the Cook Islands community.
4. Protect and enhance the TCA's biodiversity values
5. Generate income for the landowners, and
6. Develop a sustainable eco-tourism venture

In the 2003/04 season, the rat poisoning effort in the TCA was reduced to fortnightly checking and replacement of baits, rather than the weekly regime used during the recovery phase (Robertson & Saul 2005), but still carried out between 1 September and Christmas. This reduced programme was repeated in 2004/05 and 2005/06 and thereafter became standard practice because it saved considerable time and poison compared with the standard regime, yet still resulted in good numbers of fledglings observed in late breeding season searches, and then in yearlings detected in the population census the following year. (Robertson & Saul 2005).

Although the poisoning effort in the breeding season was reduced considerably, a new feature was the introduction of 'interim poisoning' with one or two complete rounds of baiting done between April and July, again using one bait per bait station, to try to reduce the standing population of rats and to achieve secondary poisoning of feral cats that had entered the TCA after the main rat poisoning period.

With the huge growth in the kākerōri population it was no longer possible to attempt to monitor the breeding performance of kākerōri, and with the introduction of the reduced rat poisoning regime, there was a concurrent reduction on time spent searching for nests and monitoring the outcome of nests. Instead of using direct measures of breeding success, fledgling counts gave immediate feedback about the effectiveness of the rat poisoning effort, and the number of yearlings detected during the annual census and 'interim' banding efforts was also used to assess the population-level success of the whole year, including from the 'interim poisoning'.

By 2007, when there were at least 277 kākerōri, it had become too time-consuming and expensive to maintain the annual census and so the annual census dropped back to biennial censuses. In order to improve the accuracy of each census, mist-netting was done in most intermediate years to try to maintain close to 50% of the population being individually colour-banded. With ongoing population growth, even this reduced monitoring effort became difficult to maintain, and so in 2017 a decision was made to reduce the frequency of the full census from every 2 years to every 3 years. At the same time, a much greater effort has been made in intermediate years to use skilled volunteers to colour-band as many birds as possible to raise the percentage colour-banded from 40% in 2015 and 2017 back to at least 50%. Record numbers of kākerōri have been banded in 2018 and 2019 (59 and 61 respectively), and so we expect that this 50% mark will be achieved by the time of the proposed 2020 census.

Table 2: Success of objectives developed for the sustainable phase of kākerōri 2001-2020 (Robertson & Saul 2004)

Objective	Achievement of objective
Monitor the survival and breeding of kākerōri on Ātiu	Achieved. Monitoring of nests and population surveys every two years after breeding was first detected has shown that the population has grown extremely well, from 30 founders in 2001–2003 (and 10 additional birds in 2011) to likely over 150 birds now.
Compare the breeding success of kākerōri breeding pairs in territories with and without rat-control	Achieved in early years (Saul *et al*. 1998, Robertson *et al*. 1998), but intensive monitoring has now discontinued. Note that data on the survival of banded birds in areas with and without poisoning continues to be collected.
Reporting results back to the Cook Islands community	Achieved through regular newspaper articles, school visits and community outreach.

Protect and enhance the TCA's biodiversity value.	Probably achieved. There is no formal monitoring nor baseline measurements for other biodiversity, but there is strong anecdotal information on the recovery of forest species such as 'Ī'oi / Rarotonga starling and moā kirikiri / Pacific fruit bats. Petrels, which are probably more sensitive to predators than kākerōri, disappeared from the TCA before it was established, and have not re-established.
Generate income for the landowners	Partially achieved. Income generated from the ecotours returns a dividend to landowners, but their income could be enhanced with better marketing effort.
Develop a sustainable eco-tourism venture	Partially achieved. The ecotours provide valuable income that more than pays for the annual rat poison, but they are still to realise their full potential. Before the Covid-19 pandemic, tours ran regularly and were generally in response to demand (especially those from cruise ships), but the active promotion of other tours was low and largely relied on word-of-mouth among the birdwatching community and from satisfied customers. In 2019, the Cook Islands Natural Heritage Trust produced a booklet "Takitumu Conservation Area Field Handbook" which gives extensive coverage of the plants and animals of the TCA, and this enhances the visitor experience.

2.4 Current population summary

During the 2017 census (and subsequent rat baiting work and banding trips) we found 471 kākerōri on Rarotonga (Figure 5). Of these, 72 were yearlings, 76 were 2-year-olds, 33 were 3-year olds, and 290 were grey birds aged 4 or more years. About 320 of these birds were living in, or immediately adjacent to, the area of the TCA which is poisoned annually, while 154 were outside of the protected area, mainly in the Lower Avanā valley below the water intake (47 birds), Upper Avanā basin (32) or in the Taipara Valley (27). A total of 186 birds (40%) were individually colour-banded, and the oldest colour-banded bird of known age was a female aged approximately 22 years and 9 months.

In 2017, the Ātiu population was about 150 birds (Ed Saul & Lynda Nia, pers. comm.). A September 2018 survey on Ātiu detected a minimum of 123 kākerōri (3 heard of unknown age, 7 yearlings, 37 2-

year-olds, 11 3-year-olds, and 65 grey birds aged 4+ years (Wright 2018). This was likely an underestimate because no colour-banded birds were recorded (compared with 7-8 seen the year before) and surveyors felt that many yearlings, were likely to be living in inaccessible areas of makatea (Tui Wright, pers. comm.).

The global population of kākerōri in 2017 was therefore about 600 birds, a more than 20-fold increase from their low point of 29 birds in 1989.

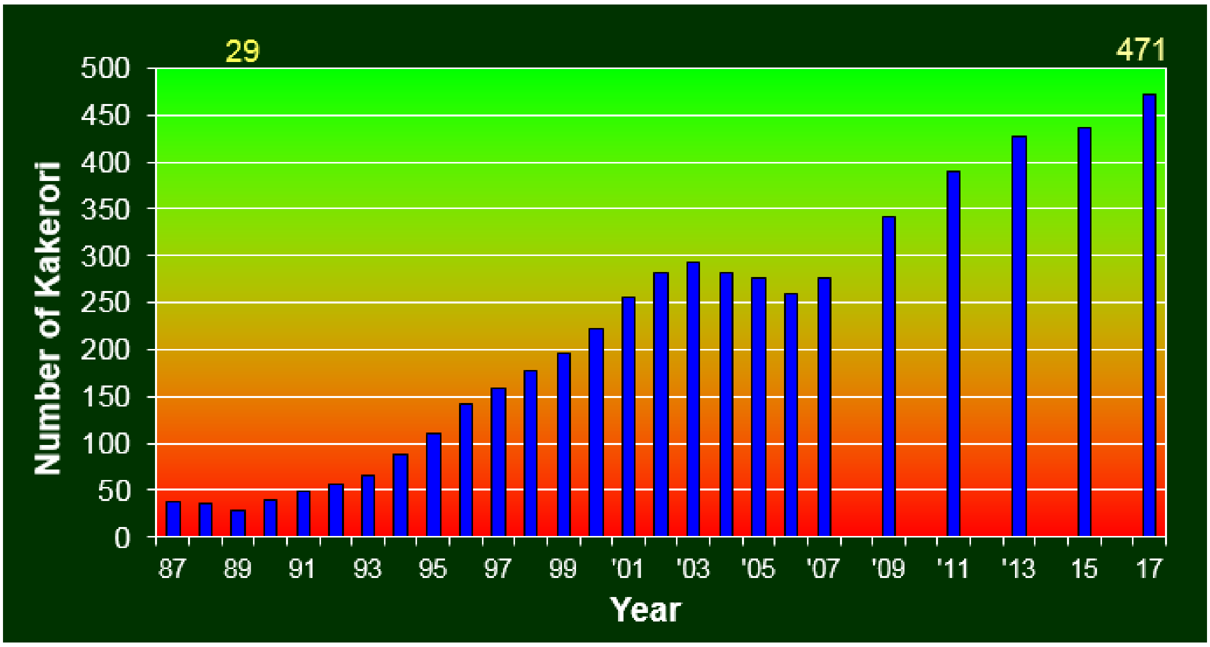

Figure 5: Population change in the kākerōri population on Rarotonga, showing the minimum of 29 birds in 1989 and the peak of 471 birds found in 2017. The dip in numbers between 2003 and 2006 was the result of removing 30 birds for translocation to Ātiu, plus the effects of five cyclones that passed through the southern Cook Islands in February-March 2005.

3. Current kākerōri management

3.1 Pest control

The rat control programme in the TCA has been very effective at allowing the kākerōri to breed successfully and for juveniles and adults to survive better than they did before rat poisoning began or in areas outside that which is poisoned annually. Nesting success was significantly better in poisoned areas (68%) than in unpoisoned areas (42%) (Robertson *et al*. 1998). Annual adult survival was also significantly better in poisoned areas (93%) than in unpoisoned areas (86%) (Robertson *et al*. 2008) and so life expectancy of adult kākerōri was doubled in poisoned areas (14 years) compared with unpoisoned areas (7 years).

Rat control aims to protect kākerōri during the breeding season, when they are most vulnerable to rat predation. Rats are controlled by replenishing fortnightly a single 18-gram wax block of Talon WB50 (active ingredient brodifacoum) placed in the middle of bait stations made from a 40 cm length of 10 cm diameter ‘Novacoil’ plastic drainpipe. To make poisoning logistically easier, bait stations are laid out along tracks following spurs, ridges and along valley floors, rather than on a grid system. In the early ‘recovery phase’ three baits were replenished weekly, and so toxin use and costs have declined markedly but still allowed solid growth of the kākerōri population. In early years, feral cats were caught in cage traps and removed from the TCA, but since about 1992, we have relied on cats being controlled by secondary poisoning after eating poisoned rats.

Pest control currently requires a four-day baiting effort every fortnight from early September to the end of December to service all the bait stations in the core management area. The bait take from the previous session is recorded, the old bait removed (taken out of the reserve) and a new bait is placed in the tube. An additional “interim” baiting round is undertaken during winter (between May and July) to suppress rats and cats outside of the breeding season.

3.2 Monitoring kākerōri recovery

The kākerōri population is monitored using two methods which require very similar data:

1. Mark-recapture techniques require a good portion of the population be caught in mist-nets (specialized very fine nylon nets strung between poles) and then unique combinations of up to four coloured plastic bands attached to their legs to identify individuals (Figure 6). Later, the number and identity of marked individuals resighted is counted, and the survival rate of individuals can be calculated, and then analysed by age and gender. Between 1987 and 2017, a minimum of 1321 kākerōri were identified, of which 732 were individually colour-banded. Since 2017, a further 120 birds have been individually colour-banded, but unbanded birds have not yet been counted. A list of the principal colour band combinations used to denote each cohort (age class) since 1999 is given in Appendix 2.

Figure 6: Processing and colour-banding kākerōri in the TCA.

2. The second method is territory mapping. Leading up to and during the breeding season kākerōri are territorial, they stay in one general location and defend it from other birds. Territorial mapping involves observing an individual or pair of birds for long enough (or regularly enough) to understand its distinct range or location. The method is relatively easy to apply to kākerōri because they sing, engage in territorial fights and are generally easily seen and conspicuous leading into the breeding season. They can also sometimes be called close to people mimicking their calls or playing their recorded calls through speakers.

The ideal time to map territories of kākerōri is around August and early September when they begin to prepare for breeding. As the population increases and expands territorial mapping has become more complex, fighting is more common and young from previous seasons are occasionally still with parent birds meaning that interpretation of data becomes increasingly complex. Having a large portion (>50%) of kākerōri individually colour-banded and knowing that most breeding kākerōri remain in their same territory year after year, makes doing a "roll call" of birds and mapping their approximate territories simpler and more accurate. Recording the numbers of unbanded individuals relies on using the four colour classes to distinguish individuals; fortunately, obvious individual plumage patterns in most 3-year-old birds and in many 2-year olds (usually based on the pattern of grey feathering on the face) allows many birds to be identified confidently. The results of the "roll call" are the minimum number of birds alive (although always a few colour-banded birds missed during the census are later identified by people doing the baiting rounds or during a subsequent census), and survival estimates by age class and sex are calculated from sightings of colour-banded birds only. Territories are depicted on A3 maps with the age class and any colour-band combinations of territory owners inside approximate territory boundaries, based on where territorial disputes were seen, but can be presented as in Figure 7 to depict the general distribution of territories.

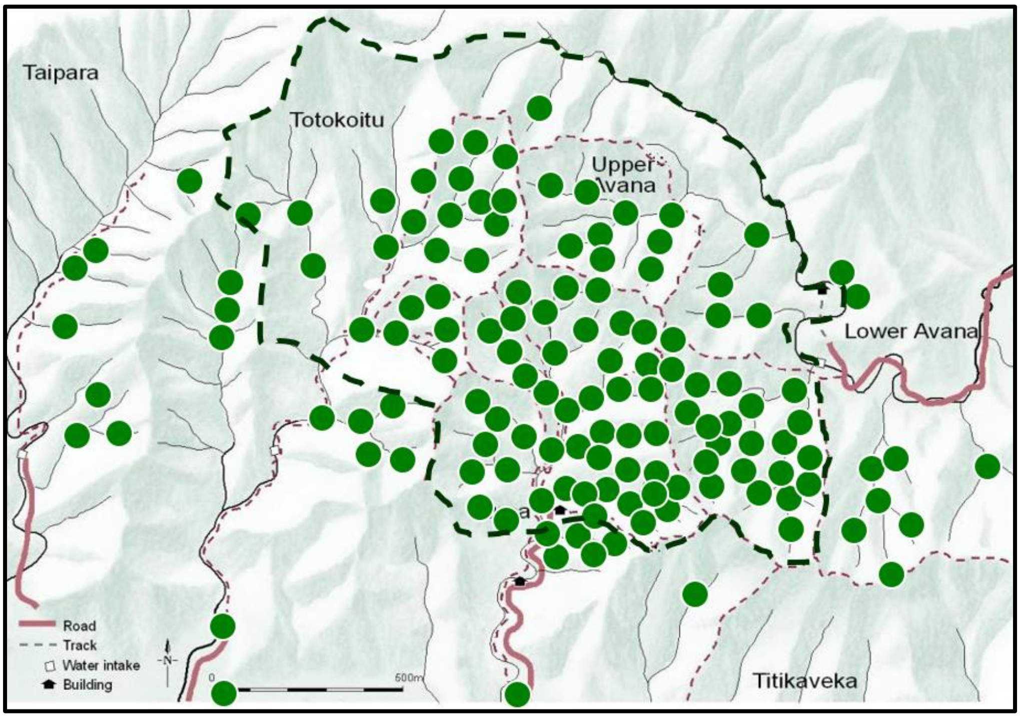

Figure 7: Map of the TCA showing the distribution of 166 pairs of kākerōri in 2015. An additional eight territories were in Lower Avanā 7 Valley, between the first and second stream crossings in the lower part of the Avanā Valley.

3.3 Benefits to other biodiversity

The pest control being done to protect kākerōri is likely to benefit other terrestrial species, particularly the other three native or endemic forest birds: ʻī'oi/ Rarotonga starling (*Aplonis cinerascens),* kūkupa/ Rarotonga fruit dove (*Ptilinopus rarotongensis*), and rupe/ Pacific pigeon (*Ducula pacifica*). Three tree-nesting seabirds, rākoa/ white-tailed tropicbird (*Phaethon lepturus*), kākāia/ white tern (*Gygis alba*), and ngōio/ brown noddy (*Anous stolidus*), all likely benefit from rat and cat control in the TCA.

Collared petrels (*Pterodroma brevipes*) used to nest in moderate numbers on valley sides at the top of the Upper Avanā basin and Tūroa Valley during the very early stages of the project but seem to be absent now. Kōputu/ Herald petrels (*Pterodroma heraldica*) are occasionally seen flying around the peaks of Te Atakura on the northern side of the main Avanā Valley, and they presumably occasionally pass over the TCA, but their numbers are very much lower than they were 30 years ago. Kermadec petrels (*Pterodroma neglecta*) have been recorded prospecting for nesting sites on the perimeter of the Tūroa Valley. The first one was seen on the Tōtoko'itu/ Tūroa Ridge in September 1990, then from 1991–1993 inclusive, from August to January, 3-10 Kermadec petrels were often circling and calling during the day near the top lookout on Outward Bound Spur, 2 were seen on the ground on the track, and others were heard calling from bush to the sides of the ridge, but are not known to have bred on Rarotonga. None has been seen in the TCA from 1994 onwards (Ed Saul, pers. obs.). The *Pterodroma* seabirds may be more vulnerable to predation than kākerōri and so additional effort specifically to exclude dogs and control feral cats and Norway rats (*Rattus norvegicus*) may be needed to restore the seabird community.

It seems that lizards have benefitted from the rat control in the TCA, judging by the numerous sightings of mōtukutuku/ inland blue-tailed skink (*Emoia impar*) and frequent sightings of moko maunga/ dandy skink (*Emoia tuitarere*) in the TCA compared with other forested areas on Rarotonga.

Moā kirikiri/ Pacific fruit bats (*Pteropus tonganus*) are conspicuous and noisy at their daytime roosts, and they have no predators apart from shotgun-wielding hunters. In 2002, 57% of the Rarotongan population, and 55% of the entire Cook Islands population, of this native fruit bat roosted at three sites within the TCA (Cousins & Compton 2005). A roost of over 200 animals has been located within the Tūroa Valley in recent years, but hunters are often warned off the TCA despite signage indicating that bats are protected in the area.

Although there is no baseline data available, we believe that general forest health, regeneration, fruiting/seeding has improved following 30 years of rat control. Rats are likely to affect regeneration by reducing fruit and/or seed production, and seed germination on the ground. We do, however, note that invasive exotic weeds, especially mile-a-minute (*Mikania micrantha*), grand balloon-vine (*Cardiospermum grandiflorum*), red passionfruit (*Passiflora rubra*), tūava papaʻā/ red strawberry guava (*Psidium cattleianum*) seem to have become more prominent and widespread over time, especially following Cyclone Nancy and the other four cyclones that passed through the southern Cook Islands in February/March 2005.

4. Future directions (2020–2030)

With the very satisfying success of management to date, and with a population robust enough to withstand events that cause minor, short term declines we have greater flexibility to adjust management over the next decade. Future management should aim to at least maintain the existing programme of rat (and hence cat) control in the TCA but take opportunities to improve the cost-effectiveness of poisoning within the existing bait station network by further reducing workload and/or bait use. This could allow an expansion of the area protected to follow the population increase and range expansion of kākerōri, and also provide greater protection of other native wildlife in and around the TCA. Changes should be made conservatively, allowing time to monitor success and should include contingencies where previous management can be re-established if new methods fail.

Objectives

- Maintain and then expand current management effort and area covered.
- Manage other threats.
- Continue work to understand the dynamics of the kākerōri population.
- Involve the local community to monitor the numbers of kākerōri on Ātiu, and encourage continued biosecurity vigilance to make sure that the island remains free of ship rats.
- Measure, protect and enhance other valuable biodiversity in the TCA.
- Engage the Cook Islands community in visiting the TCA.
- Ensure sustainability of the TCA into the future

4.1 Maintain and then expand current pest control effort and area covered

There is potential to further reduce the use and costs of toxin, or to expand effort at the same cost to other valleys on Rarotonga. The bare minimum is to maintain the current programme of rat-poisoning in the Tōtoko'itu, Tūroa, and Lower Avanā Valleys on Rarotonga, the core area used by kākerōri.

4.1.1 Change pest control frequencies

Investigate whether the frequency of baiting could be further reduced. For example, baiting could start with fortnightly baiting for 3 rounds in September and early October, when bait take is usually very high, then move to 3-weekly baiting for the remainder of the period when bait take is usually low, and hence cut out 2 (22%) of the usual 9 rounds of baiting.

The "interim" bait round in May-July should be maintained. It appears to have been effective because we have recorded sustained growth of the kākerōri population since it was introduced. Although we do not have any index of feral cat abundance, this pulse of poison should theoretically control any feral cats that have re-colonised the TCA since the main baiting season.

Indexing both rodent and cat numbers in the TCA by using baited camera traps may help to show the effectiveness of rat poisoning makes and provide an immediate measure of the effect of any changes before the outcome for kākerōri was known.

4.1.2 Use different pest control methods

The TCA should continue looking for ways to reduce cost of effective rat control.

The continuing use of existing bait stations is probably the most cost-effective method available, but there may be cheaper poisons than Talon WB50 that are equally effective at controlling rats and controlling cats through secondary poisoning. A previous trial of bait hoppers, dispensing hundreds of baits, proved ineffective in the TCA because rats were reluctant to remove baits (Ed Saul, pers. comm.).

Self-resetting traps, such as Goodnature A24 traps which can kill up to 24 rats between each service, are intrinsically appealing. However, they have extremely high set-up costs (currently A24s cost >$200 per complete unit) plus ongoing costs of lures and gas canisters to drive the mechanism. If the initial hardware costs (c. $80,000 for 400 units) were funded externally, the ongoing maintenance costs could be met locally. A separate feral cat control programme (traps or toxins) would be needed because A24 traps do not kill cats, and instead provide a ready source of dead rats for them to scavenge. This feral cat control might be done by continuing to use rat poison in bait stations along likely entry points from the lowlands in the Tōtoko'itu, Tūroa and Avanā valleys, or with PAPP (para-aminopropiophenone), a toxin which has been developed and registered in New Zealand for control of feral cats.

4.1.3 Extend predator control

Protection of kākerōri does not need to be confined to the current management area. There is potential to expand pest control to other valleys in the TCA, or beyond, if the current management can be further streamlined. Four areas in particular could be considered, in decreasing order of importance: the Upper Avanā Basin, Lower Avanā 7 valley, Lower Avanā 4 valley and Tōtoko'itu 8 valley, because each holds 5+ pairs of kākerōri in a compact area (<15 ha of baiting required), and the sites are easily accessible (Figure 8). The Upper Avanā Basin has a network of bait stations that were used in 1992 only, and this network could be re-opened relatively simply. The Taipara Valley sometimes has a considerable spillover of kākerōri from the TCA, but an effective poisoning operation there would require a large-scale and dedicated effort.

These sites could be used as places to trial new pest control methods because we have existing data on kākerōri numbers and their survival in these valleys. For example, a trial of A24 self-resetting traps could be done in the Upper Avanā Basin or in Avanā 7 Valley to decide if this trap could be a cost-effective method to improve core management.

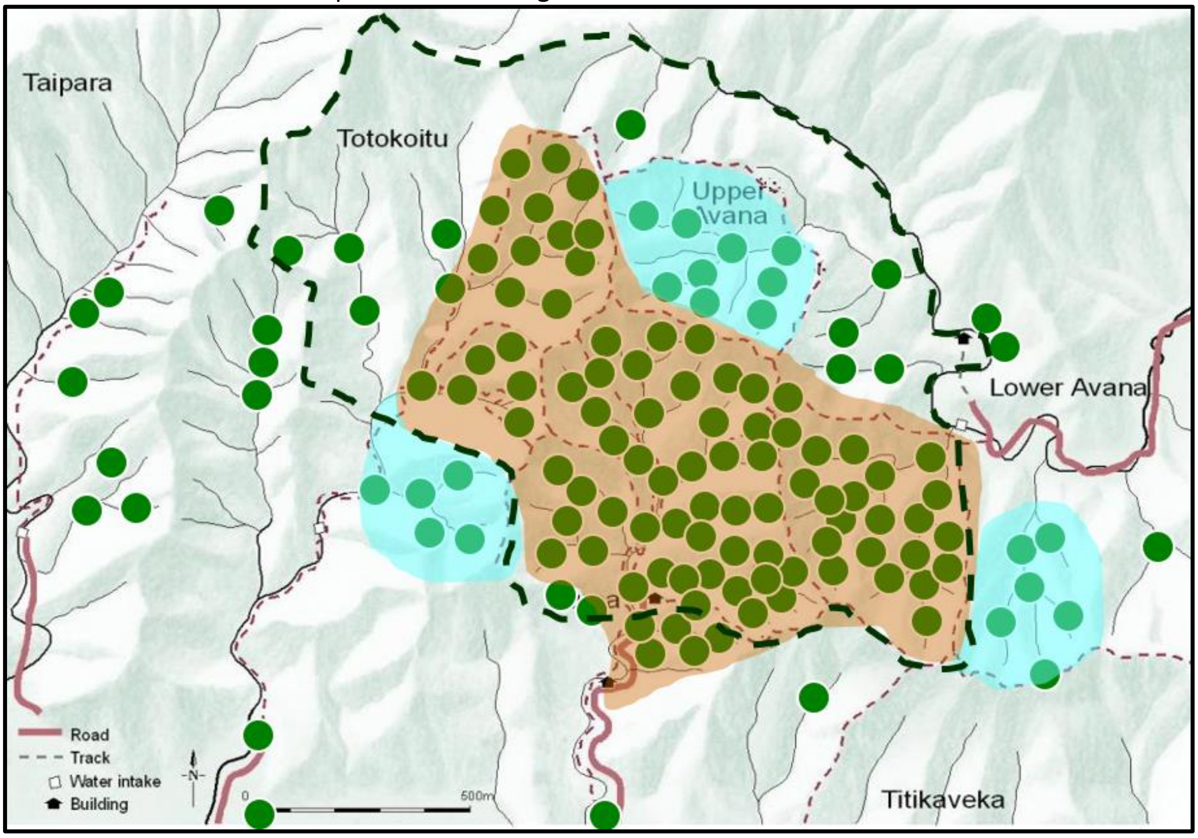

Figure 8: Map of the TCA showing the distribution of kākerōri pairs in the area treated with poison (shaded brown) and in three of the four potential areas for expansion (shaded blue). The Lower Avanā 7 Valley, between the first and second stream crossing in the lower part of the Avanā Valley, is not shown.

4.1.4 Opportunity to create rodent-free Cook Islands

New Zealand has recently committed to developing ways to become predator free (of possum, rats and mustelids) by 2050, and is investing heavily in the development of methods (eradication and biosecurity) to achieve this. To test these developments at a smaller scale, they plan to remove these pests from large offshore islands with small permanent human populations (e.g. Great Barrier Island, Stewart Island) where new tools can be tested at a smaller scale.

The Cook Islands might profitably assist New Zealand to develop and test rodent eradication tools and develop follow-up biosecurity practices to keep inhabited islands free of pests. The Cook Islands is an archipelago with a variety of island sizes and topographies, some inhabited, many not. If eradication and prevention of re-invasion was successful on small inhabited islands, with challenges in protecting livestock (such as goats, pigs, cattle and horses) and pets (dogs and cats) from any poison used, the same technology could then be scaled-up to treat Rarotonga. If rodents could be successfully eradicated from the Cook Islands, and not allowed to re-invade via ships and yachts, there would be huge financial, human health and conservation gains to be made.

The TCA should promote the concept of rodent-free Cook Islands, and advocate that the Cook Islands government follows the development of rodent eradication methods in New Zealand, with the view to offering to trial some of the methods on small but inhabited islands.

4.2 Manage other threats

4.2.1 Developments

Developments such as re-establishing the complete inland ring road or allowing new buildings, including new dams or houses, have the potential to increase risks for kākerōri. This is particularly so as the kākerōri population grows and expands towards the forest edges, and people build houses further into the hills. Kākerōri are now occasionally found in trees adjacent to taro plantations. Developments have a range of risks that need careful consideration including:

- Direct reduction of habitat from development
- Attracting other pests (animals or plants) through greater access, human activity or by changing surrounding landscapes.

4.2.2 Feral pigs, goats & moa rere-vao/ feral chickens

Straying pigs and goats are mostly absent from the TCA because their owners quickly recover them. Moa rere-vao/ feral chickens breed in the TCA and each year a few are poisoned when they remove baits from bait stations, thus making the rat poisoning less effective. These domestic animals present a potential risk to human health if they have eaten toxic baits in the TCA, and so it is important that signs are erected at entry points into the TCA warning hunters of the risks, and warning them of the risks to accompanying dogs of secondary poisoning.

In the general absence of pigs and goats, the forest understorey and floor vegetation is intact and healthy, especially on the spurs and ridges. This vegetation is probably important to kākerōri by providing habitat for invertebrate food, and it may also provide extra protection when storms damage the outer canopy.

4.2.3 Biosecurity

Because Rarotonga is the main international arrival point for aircraft and shipping, and has the largest human population in the Cook Islands, its wildlife is most at risk from the accidental or deliberate importation of new avian diseases (e.g. mosquito-borne haematozoa of *Plasmodium* sp., or 'Asian bird-flu') or other new animal species that could harbour diseases, be competitors or be predators of kākerōri. For example, the accidental introduction of brown tree snakes (*Boiga* *irregularis*) to Guam, western Pacific, led to many range reductions and extinctions of forest birds (Savidge 1987).

Chan *et al.* (2011) postulated that there may be a direct relationship between a loss of genetic diversity and decreased disease resistance in kākerōri. They predicted that the kākerōri population, which has low genetic diversity relative to most other bird species after passing through a bottleneck of 29 birds in 1989, might be highly susceptible to introduced avian diseases. Although avian diseases could potentially be carried to Rarotonga by migratory birds, such as the karavia/ long-tailed cuckoo, they recommended that great care must be taken to ensure that any pet birds imported to the Cook Islands are free of diseases. They went on to suggest that survival of the kākerōri could not only depend on ongoing rat control, but the detection and management of possible new threats which includes disease and other bird species. Two cage-escaped crimson rosellas (*Platycercus elegans*) were seen in the TCA in August 2005 by Ed Saul and Diana Dombroski, low numbers of eastern rosellas (*Platycercus eximius*) have been seen in and around the TCA since about the same time (although all are believed to be males and so will die out eventually) and jungle mynas (*Acridotheres fusca*) became established on Rarotonga some time before 2009 (Mitchell 2009), but have not yet been seen near the TCA.

4.2.4 Cyclones

In the 14 years between 1969 and 1983, Thompson (1986) recorded that an average of 1.4 tropical cyclones (with mean wind speeds > 33 knots (61 km/h), and strong enough to damage human structures) affected the southern Cook Islands each summer or early autumn. Five of the 19 tropical cyclones were classified as hurricanes, with mean wind speeds of > 63 knots (117 km/h), and they were usually accompanied by great destruction. Between 5 February and 6 March 2005, five tropical cyclones ('Meena', 'Nancy', 'Olaf', 'Percy' and 'Rae'), including four that reached hurricane force at some stage, swept through the southern Cook Islands, generally on a northwest to southeast bearing (Figure 9).

The 2004/05 cyclone season had the highest number of cyclones ever recorded in a single season in the Cook Islands, and cyclone 'Percy' recorded the lowest barometric pressure (900 hPa) ever measured in the South Pacific (Ngari, 2005).

- Cyclone 'Meena' passed to the east of Rarotonga on 5 and 6 February 2005, with maximum sustained winds on Rarotonga of 46 knots (85 km/h) and gusts of 64 knots (119 km/h), 107 mm of rain, and serious damaging sea-surge.

- Cyclone 'Nancy' passed close to Ātiu, the site of the newly-established population of kākerōri, in the early hours of 15 February 2005 and uprooted many trees, and then it continued southwards until turning westward to hit Rarotonga that afternoon, before moving away only slowly to the south and southwest. The accompanying 53 knot (98 km/h) winds with gusts to 88 knots (163 km/h) on flat land (but probably much stronger in the hills) on Rarotonga caused severe damage to trees on southward-facing slopes, spurs and ridgelines within the TCA. Luckily, this cyclone, which had earlier been classified as a Category 2 cyclone (sustained winds of 84–96 knots), had weakened to tropical storm force by the time it reached Rarotonga, otherwise the damage would have been considerably worse.

- Cyclone 'Olaf' passed to the west of Rarotonga on 17 February and caused more heavy rain and serious sea-surge damage, but the winds on Rarotonga reached only tropical storm force at 38 knots (70 km/h) with gusts to 51 knots (95 km/h).

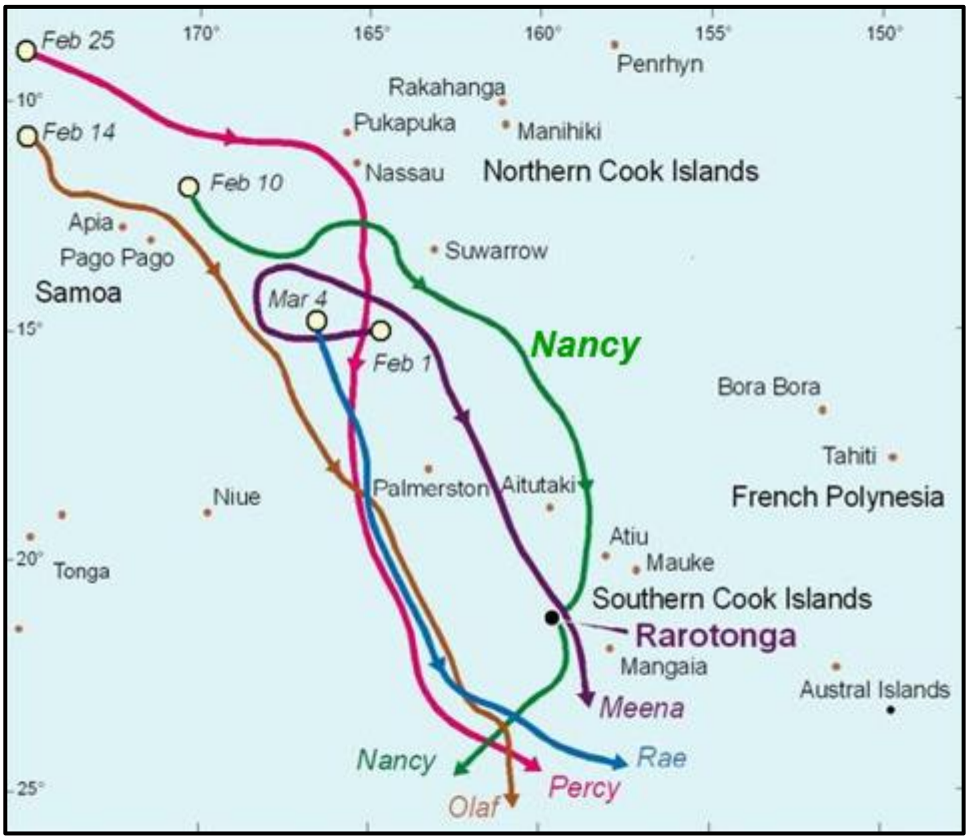

Figure 9: Map showing tracks of five cyclones that passed through the southern Cook Islands in February – March 2005.

- Cyclone 'Percy' and cyclone 'Rae' passed to the west of Rarotonga on 3 March 2005 and 6 March 2005, respectively, and again both were accompanied by rain, strong winds (> 30 knots, 56 km/h) and storm surges (Robertson & Saul 2006).

These five cyclones that hit Rarotonga in late summer 2005 had the potential to be catastrophic for kākerōri and reverse many years of management; however, the birds survived relatively well, albeit at the lowest survival rate recorded since management began in 1989. The kākerōri population on Rarotonga declined by 2.5%, from 281 birds in August 2004 to a minimum of 274 birds in August 2005 (Figure 5). This was the largest annual decline recorded since management began in 1989 (Robertson & Saul 2007).

Of the 150 banded kākerōri known to be alive in August 2004, 35 (23%) were not found during the August 2005 census and were assumed to have died. This was much higher than the 11% annual mortality rate recorded between 1989 and 2004. The mortality in 2004/05 was not evenly spread across age cohorts; it was especially high (31%) among 58 young adults (1–3 years old), but extremely so among very old birds (i.e. 80% of the 5 birds aged over 20 years) (Robertson & Saul 2007).

Perhaps the most important effect of the cyclones was not seen until the following breeding season, when the general widespread reduction of canopy cover meant that nests were particularly exposed to the heavy and persistent rain encountered that year. As a result, recruitment of kākerōri in the 2005/06 breeding season was poor with only 31 yearlings detected compared with 50+ in most other years since 2001 (Robertson *et al*. 2009). There was significant damage to the track infrastructure from fallen trees and branches, and the cyclone damage opened up areas for the invasion of weeds.

The events highlighted the importance of having available a contingency fund to allow a quick response to fixing damaged tracks and roads, which allowed the 2005 baiting to be run efficiently and on time.

4.2.5 Weeds

An assessment of weeds in the Cook Islands identified the 15 top species for their impact on natural habitats and agricultural land, which could be candidates for biological control (Dodd & Paynter 2012). Some of these weed species are invasive in parts of the TCA including mile-a-minute, grand balloon vine, red passionfruit, kōʻīʻī / African tulip tree (*Spathodea campanulata*), tūava papaʻā/ red strawberry-guava, and kūrima/ pellate morning glory (*Decalobanthus pellatus*). We have also observed wax vine (*Hoya australis*) as a problem plant in the TCA, and kōpī muramura/ red ginger (*Alpinia purpurata*) grows in valleys close to the TCA and should be removed as soon as possible if it spreads to the TCA. None of these weed species is favoured as a nesting site by kākerōri (Saul et al. 1998).

In the past decade, Manaaki Whenua Landcare Research scientists from New Zealand have been working with Cook Islands officials to develop a biological control plan for the 15 top weed species (Dodds & Paynter 2012), and have already had some early successes with the successful introduction of red postman butterfly (*Heliconias erato cyrbia*) to control red passionfruit, and a rust fungus (*Puccinia archavaletae*) to control grand balloon vine, a scale insect (*Tectococcus ovatus*) to control tūava papaʻā/ red strawberry-guava, and a gall-forming mite (*Colomerus spathodeae*) to control the kōʻīʻī / African tulip tree.

The TCA should partner with other conservation organisations, such as Te Ipukarea Society, National Environment Service, and even SPREP, to support scientific programmes to use biological control to overcome exotic weed problems in the Pacific, and especially to push for the control of weeds of significance to the TCA. The whole structure of the native forest environment on Rarotonga is threatened by exotic weeds such as tūava papaʻā/ red strawberry-guava that forms monocultures in disturbed sites, and various invasive vines that cause canopy collapse.

4.3 Continue work to understand the dynamics of the kākerōri population

4.3.1 Monitoring

Monitoring effort is becoming increasingly difficult as the population grows and expands its range. The kākerōri population census changed from annual monitoring to 2-yearly monitoring in 2009, and then to 3-yearly monitoring after 2017. Having the first three year classes of kākerōri distinguishable from their plumage and/or bill colours allows an accurate estimate of the age structure of the population. If the census cycle were longer than 3 years, we would lose the ability to keep track of the age structure of the population because unbanded grey birds (4+ years old) could not be assigned to a particular cohort. A review should be carried out after the first 3-yearly census to determine if this frequency should be maintained or changed back to 2-yearly.

An annual banding effort is the best way to maintain a high proportion of the total population that is banded. Because many yearlings are caught during the colour-banding, annual banding also provides an estimate of the success of the management in the previous breeding season. As techniques develop there may become more cost-effective methods to estimate or index the population change, although it is unlikely that other methods (such as acoustic recorders, call counts, or transects) will be as accurate or compelling as the current territory mapping methods, but they may be cheaper and less labour intensive.

With 33 years of monitoring we already know a lot about the population and are watching how it changes as the density of birds increases. Further understanding will be gained from:

- Comparing breeding success from early in the programme vs current.
- Investigating how family group size change over time.
- Investigating how does age affects breeding success, and how age at first breeding has changed as the population has grown?
- Comparing annual survival rates over time by sex and by age class, inside and outside the poisoned area.

A key to answering some of these questions is accurate ageing and sexing of kākerōri. Ageing techniques appear to be accurate, except that a small portion of 3-year old birds appear indistinguishable from 4^{+}-year old birds in the field (though the 3-year-olds often retain a few orange feathers when examined in the hand). Sexing techniques are more problematic; there was a 94% agreement between field sexing based on five linear measurements and weight by one experienced observer and DNA sexing from analysis of breast feather samples, but the agreement is generally likely to be much less than this because there is a lot of variation in the way different people measure kākerōri (Zhao *et al*. 2009).

Inexperienced observers are prone to record measurements that lie outside the usual range of measurements taken by experienced observers, and so this makes it difficult to determine the sex of banded birds by measurements alone. Special attention is needed to train people to take measurements consistently and to double-check any measurements recorded outside the normal range of variation. In general, feather sexing will be more reliable than field measurements, but it is costly and there is a long time lag between collection and analysis. To answer some of the above questions, we need to spend about $10,000 ($35 per sample) to get commercial DNA sexing of the feather samples collected in the past decade, and to budget $2000 per year for sexing of samples collected between and at each full census.

4.3.2 Research

A number of research questions to improve management of the TCA, and allow conservation managers to understand demographic processes of kākerōri as it recovers, and to better understand the ecology of other threatened species in the TCA include (in no particular order):

- Research the distribution, movements, territoriality, population dynamics and survival of ‘ī’oi/ Rarotonga starling and the kūkupa/ Rarotonga fruit dove, to find out if the current pest control adequately protects these two species that are classified by BirdLife International as ‘Vulnerable’.
- Understand how the life history and demography of kākerōri has changed as the population increased and expanded.
- Compare the survival and breeding success of kākerōri in territories with and without rat-control.
- Determine the abundance of feral cats in territories with and without rat-control.
- Determine with camera traps whether residual feral cats in the TCA are attracted to the smell of nesting material introduced from kōputu/ Herald petrel colonies elsewhere on Rarotonga and, if not, then test to see if feral cats are attracted to playback of petrel calls at a time of day and time of year when petrels are unlikely to be attracted.

The TCA manager should maintain and promote a register of research questions, and maintain a database of research papers and reports on kākerōri and other wildlife of relevance to the management of the TCA.

4.4 Monitor the survival of kākerōri on Ātiu and engage the community

After careful consideration of factors such as island size and topography, habitat availability, predators, competitors, disease risk and community attitudes, Ātiu was chosen as the best island for the establishment of an insurance population (Robertson *et al*. 2006). Thirty birds were transferred there between 2001 and 2003, and an extra 10 founders were added in 2011. In 2017, the Ātiu population was about 150 birds (Ed Saul & Lynda Nia *pers. comm*.). During a brief survey in September 2018, Wright (2018) detected a minimum of 123 kākerōri (113 of which were 2 or more years old), but she felt that others were likely to be living in inaccessible areas of makatea (Tui Wright, pers. comm.).

It would be valuable to collect feather samples from 20 or more kākerōri on Ātiu to understand the genetic make-up of the current population and estimate how many founders contributed to the current population. To maintain genetic diversity of the Ātiu population, Mathew Chan (pers. comm.) recommended that 10 individually colour-banded juveniles (1-2 years old) should be translocated from the TCA to Ātiu every 20 years (or 5 birds every 10 years). This would require TCA landowner support, and support from the Ātiu Island Council, but would be a small price to pay for extra insurance and would not adversely affect the TCA population unduly.

Getting an accurate census of the population on Ātiu is difficult because of the rugged makatea area. The monitoring should be done, with support from the local community, at least every 3 years so that the number of young birds in each of the recent cohorts can be determined. When genetic samples are taken of Ātiu birds, all kākerōri handled should be individually colour-banded to help refine later population estimates.

4.5 Protect and enhance other valuable biodiversity in the TCA

Little is known of how other species have responded to the annual reduction in rat and (presumably) cat numbers from the kākerōri management. Other studies could be undertaken to understand if there are opportunities to expand the benefits to other species.

- Investigate the population dynamics and movements of ‘ī’oi/ Rarotonga starling to determine population size in the TCA and map their home ranges - despite colour-banding about 10 birds in the TCA since 1987, none has been resighted in the TCA nor reported elsewhere. Investigate if ‘ī’oi/ Rarotonga starling will use predator-proof artificial nest boxes, because this would allow easier research and at the same time increase their productivity.

- If research shows a very low residual abundance of feral cat following the rat poisoning programme, work with Te Ipukarea Society and international organisations such as the Northern New Zealand Seabird Trust, Department of Conservation and SPREP, to investigate the opportunity to passively reintroduce petrels to the TCA by broadcasting their calls from loudspeakers and providing suitable weather-proof and cat-proof burrows nearby. This technique has been successful in New Zealand and Hawaii but would rely on maintaining a very high standard of rat and cat control in the immediate vicinity of the site. We suggest that a site in the heart of the rat control area (such as near the top of Tūroa 2/8 spur, or near the Tūroa/ Tōtoko’itu/ Upper Avanā Peak) be considered for an initial trial, with trail cameras set to record visits by petrels and predators.

- Introduce systematic monitoring of other bird species inside and near to the TCA, including index counts from acoustic recorders, 5 minute bird counts, timed hilltop counts of kūkupa/

Rarotonga fruit dove, rupe/ Pacific pigeon, ‘ī’oi / Rarotonga starling and seabirds (rākoa/ white-tailed tropicbird, kākāia/ white tern, and ngōio/ brown noddy). Carry out dusk counts of moā kirikiri/ Pacific fruit bats leaving their roosts, supplemented with daytime counts and photographs of roosts. Calibration of these indices against known population density would greatly improve confidence in these techniques. These data would be compared between areas to make ‘bird and bat health’ reports for each species or species group.

- Introduce systematic monitoring of lizards inside and outside the TCA, using techniques such as pitfall traps, Onduline/ corrugated iron shelters, tree bands, or weta hotels (for geckos). If pest control is expanded to new areas, carry out before/after monitoring in the new areas and in non-treatment areas.

- If the original data can be located, resurvey the vegetation plots that were established in the early years of the TCA to record changes in abundance of both native plants and weed species. The plots were marked with low metal pegs that are still dotted about the TCA. Establish new plots, if required.

- Work with the Cook Islands Natural Heritage Trust to develop an identification guide to rare plants in the TCA, including southern charpentiera (*Charpentiera australis*), Rarotonga cyrtandra (*Cyrtandra rarotongensis*), au‘ere/ grewia (*Grewia crenata*), Polynesian melicope (*Melicope bracteata*), Rarotonga ground-orchid (*Habenaria amplifolia*), and yellow malaxis orchid (*Malaxis reineckeana*); and map, tag and count them during each kākerōri census.

4.6 Engage the Cook Islands community in understanding and supporting the programme

There is scope for the TCA to foster a ‘Friends of kākerōri’ or ‘Friends of the TCA’ group of interested people and government staff, and get Department of Conservation staff to develop a training programme to get to a stage where local people are able to carry out mist-netting and colour-banding of kākerōri, do the kākerōri census, undertake other wildlife monitoring, and to assist with pest animal or plant control in and around the TCA.

The Rarotongan and Cook Island communities are already well engaged with kākerōri conservation, and there are regular school visits to the site led by TCA staff and by Te Ipukarea Society staff. Nukutere College even included the kākerōri in their science curriculum, and pupils were encouraged to find out as much as they could about the bird and its management. The continuation of these visits is strongly supported, but we believe that the experiences can be further enhanced by providing bilingual brochures or pamphlets (in English and Cook Islands Māori) and high quality photomontage posters, such as the one produced by Lynda Nia, aimed at particular age-group audiences, and providing bilingual display panels at the TCA office and or TCA shelter, that are rich on images, maps and graphs, and therefore suitable for all age groups and nationalities to understand.

Interpretation signage of important plants (native, Polynesian introduced and weed species) along the tourist tracks is useful, but could be expanded to include a wider range of species and a description of their traditional uses and/or ecological impacts. New plantings of native and Polynesian introduced plant species, with interpretative signage, would enhance the visitor experience.

Catering for free guided visits by the local Cook Islands community is vital in these difficult times following the Covid-19 pandemic. Without 170,000 international visitors per year, people have the opportunity to learn about and appreciate the natural world that is in their backyard. In New Zealand during Covid-19 lockdown, there was a huge increase in the number of visits to internet sites describing native backyard birds.

4.7 Ensure the sustainability of the TCA into the future

Keppel *et al.* (2012) used the TCA in a case study that showed that there are four common themes in successful Pacific conservation projects: active participation and leadership of landowning communities, involvement of all relevant stakeholders, generation of tangible benefits for landowning communities, and external support for the project over long time periods. They felt that the success of the TCA and the kākerōri programme could be attributed to the sustained achievement of all these themes throughout the 25 years this programme had been running to 2012.

A fundamental problem with the current informal TCA structure is its lack of legal standing which makes it difficult to solicit funds or own property. The success of the TCA has relied very much on the goodwill and ongoing support of the three land-owning families, but the solution lies firmly in the hands of the landowning families because the TCA is their land, nobody else's. A possible avenue would be to incorporate themselves, with others if they wished, as a trust. Forming a trust seems preferable to forming a society because a trust satisfies all legal requirements but does not carry the same reporting or accounting burden that an incorporated society does.

To ensure the ongoing success of the project, and to give greater resilience into the future we need to increase the number of paid people and/or volunteers with the skills to provide continuity for the ongoing recovery project and the long-term management of the TCA. These part-time roles would include:

- The manager of the TCA (Ian Karika's role) needs to maintain oversight of the entire programme and keep the various activities (Appendix 3) on schedule throughout the year.
- The manager's position needs a deputy or understudy to pick up the role when the manager is unavailable.
- Pest control officer(s) with knowledge of kākerōri and other species in the TCA, and confident working on the steep and slippery tracks.

- Maintenance officer(s) to keep public tracks, baiting tracks and the road clear and safe, and keeps the water pump, shelter, office and cottage in good working order.
- Tour guide(s) with a sound knowledge of the kākerōri and other species in the TCA, especially the traditional uses of plants growing along the public tracks.
- Ecologist(s) or volunteers to carry out, or assist with, monitoring kākerōri and other species in the TCA, including colour-banding and censuses, and to answer general scientific questions and train field staff and guides.

Succession planning is required urgently to identify what is needed for each of the roles (skills, time, costs) and where those skills lie (TCA families, Cook Islanders as local employees, local NGOs (e.g. Te Ipukarea Society Inc., Friends of Kākerōri), government staff, New Zealand conservation volunteers).

The Covid-19 pandemic that struck in early 2020 almost instantly turned the international tourism market on its head and saw the Cook Islands close its borders to all non-residents for months in a successful move to remain free of the deadly virus. A likely outcome from the loss of the tourist industry for an unknown length of time is a likely exodus of people that were formerly employed in the tourism/hospitality industry, and many who do not leave will be looking for alternative employment, which could include part-time roles in the TCA, especially for family members with experience in the tourism/hospitality industry.

Before the pandemic, there seemed to be potential to significantly increase the number of ecotours and volume of visitors without compromising the conservation values of the TCA. This would have had the benefit of increasing the revenue for the project and for landowners, and to provide more sustained and predictable income for the person/people running the ecotours. Alas, this will not be possible for some time.

The pre-Covid ecotours relied on regular cruise ship visits, birding and natural history networks, and by word-of-mouth from one satisfied customer to another. It is hard to predict the long-term effects of the pandemic on international tourism, and ecotourism in particular, but it may take some time before the situation returns to the pre-Covid situation once a reliable vaccine is widely available. Airlines are likely to resume flying tourists to Rarotonga first, but it is likely to take very much longer before the cruise ship market picks up after Covid-19 because of the reputational damage arising from a few cruises which were hit hard by Covid outbreaks.

The TCA was already geared up to tap into a niche market of keen birders and naturalists, and it is likely that this market will return to normal sooner than the majority of 170,000 per annum standard international tourists who are drawn to Rarotonga’s beaches, lagoons and winter warmth. An advantage of concentrating in the next few years on this niche market is that these customers are particularly keen and interested in the experience, and are probably fitter than the average cruise ship passenger. The niche birder market is small, but the BirdLife International network that Te Ipukarea Society taps into as the Cook Islands partner, can reach a large audience of wealthy people who wish to see and “tick off” or “list” new species, or to see a very successful conservation programme in action.

If the TCA is to significantly increase its revenue, it needs to be geared up to also tap into the standard tourist market as it resumes, taking advantage of opportunities to offer employment to experienced family members involved in tourism and hospitality ventures that have been forced to close. The good thing is that the TCA has a sound infrastructure and very few overheads, and so should be able to continue to offer ecotour experiences as soon as the tourism market re-opens. Attention needs to be paid to advertising to make sure that visitors have sturdy footwear and realise that the tour is along tracks and includes a modest climb, rather than being only along a road, but mosquito repellent should be supplied rather than mentioned in brochures as being required! The pricing of TCA tours seemed very modest for such a high-quality experience, but perhaps this resulted in more donations to the project than if the tour cost were higher.

The TCA needs to improve its advertising that targets the ecotourist community by, for example, working in partnership with New Zealand ecotour operators at events such as the annual RSPB bird fair in the United Kingdom, and targeting standard tourists by placing brochures at the International Airport and at hotels.

The outer room of the current office at Takitumu needs to be renovated and presented as a visitor centre with interpretation panels (predator impacts, kākerōri natural history, botany, other wildlife) with brochures/ booklets for sale and, only when general tourist numbers and cruise ship tours pick up, potentially include appropriate souvenirs to spread the word wider.

In the meantime, until tourism picks up, the TCA needs to seek funds from international environmental donors to maintain the core rat poisoning programme that is fundamental to the ongoing success of saving the kākerōri, and protecting other endemic birds and valuable wildlife in the conservation area.

5. Recommendations

Pest control and threats

- The bare minimum is to maintain the current programme of rat-poisoning in the Tōtoko'itu, Tūroa, and Lower Avanā Valleys on Rarotonga, the core area used by kākerōri.
- Investigate whether the frequency of baiting could be further reduced.
- The "interim" bait round in May-July should be maintained.
- Index both rodent and cat numbers in the TCA by using baited camera traps. may help to show the effectiveness of rat poisoning.
- Continue looking for ways to reduce cost of effective rat control.
- Investigate using self-resetting traps, such as Goodnature A24 traps which can kill up to 24 rats between each service.
- Consider using PAPP (para-aminopropiophenone), a toxin that has been developed and registered in New Zealand for control of feral cats.

- Consider expansion of pest control to other valleys in the TCA, or beyond, if the current management can be further streamlined.
- Promote the concept of rodent-free Cook Islands, and advocate that the Cook Islands government follows the development of rodent eradication methods in New Zealand, with the view to offering to trial some of the methods on small but inhabited islands, before scaling-up to Rarotonga.
- Respond quickly to threats to nature in the TCA, such as roading or housing developments, feral animal incursions, biosecurity, cyclones and weed encroachment.
- Erect signs at entry points into the TCA warning hunters of the risks of secondary poisoning from eating feral animals that have strayed into the TCA.
- Maintain a contingency fund to allow a quick response to fixing damaged tracks and roads following cyclones.
- Partner with other conservation organisations, such as Te Ipukarea Society, National Environment Service, and even SPREP, to support scientific programmes to use biological control to overcome weed problems facing the TCA.

Kākerōri and other native wildlife

- Continue to monitor the demography of kākerōri by catching and marking birds with a unique combination of coloured leg bands.
- Support 2- or 3-yearly census by doing a “roll-call” of banded birds and mapping their territories.
- Review the frequency of censuses after the first 3-yearly census to determine if 2-yearly censuses are more practical.
- To answer questions about the demography of kākerōri, about $10,000 ($35 per sample) is needed to get commercial DNA sexing of the feather samples collected in the past decade, and to budget $2000 per year for sexing of feather samples.
- Continue to monitor the kākerōri population on Ātiu at least every 3 years.
- With the consent of TCA landowners and the Ātiu Island Council, aim to add 10 new founders to the Ātiu population from the TCA every 20 years, or 5 new founders every 10 years to maintain genetic diversity of the ‘insurance’ population on Ātiu.
- When kākerōri are handled on Ātiu, genetic samples should be taken and all birds should be individually colour-banded to help refine subsequent population estimates.
- Improve knowledge of the benefits that other native wildlife receives from the rat and feral cat control programme.
- Support research aimed at improving management of the TCA, such as studies of the ecology of ‘ī’oi/ Rarotonga starling and kūkupa/ Rarotonga fruit dove; studies comparing the survival of kākerōri or the abundance of feral cats in territories with and without rat-control, and

determining with camera traps whether residual feral cats in the TCA would pose a risk to petrel if they were to be attracted back using playback of their calls.

- Introduce systematic monitoring of other bird species, moā kirikiri/ Pacific fruit bats, and lizards inside and near to the TCA.

- Re-survey the vegetation plots that were established in the early years of the TCA to record changes in abundance of both native plants and weed species.

- Work with the Cook Islands Natural Heritage Trust to develop an identification guide to rare plants in the TCA, and map, tag and count them during each kākerōri census.

Education and Sustainability

- Improve the educational resources about the TCA by updating bilingual brochures, booklets, photomontage posters and display panels at the TCA office and/or TCA shelter, and on interpretation signs along the tracks.

- Concentrate on providing a high-quality natural history experience for Cook Islanders, especially for school groups. Work with school teachers to tie learning experiences in the TCA in with the school curriculum, along the lines that Nukutere College already does.

- Initially target the niche birder/ naturalist market when international tourism resumes following the Covid-19 pandemic.

- Consider establishing a trust of the landowner representatives, and possibly others, as a formal legal entity to seek and manage funds from environmental donors.

- Maintain a contingency fund to allow a quick response to fixing damaged infrastructure as a result of cyclones or other storm events.

- Department of Conservation staff involved in the kākerōri programme should develop a training package to get core group of local people skilled at mist-netting and colour-banding so that they can eventually run the kākerōri monitoring programme and undertake the census, as well as undertake other wildlife monitoring projects.

- Carry out urgent succession planning to ensure continuity in staffing and volunteer support for managing the TCA, doing the rat poisoning, doing the banding and census work, and running ecotours and school visits.

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Appendix 1. Kākerōri ecology

The kākerōri is a small (22 g) mainly insectivorous forest passerine, endemic to Rarotonga. Kākerōri were very common throughout Rarotonga in the mid-1800s, including on the coastal ring plain; however, their numbers declined rapidly, and their range became restricted to the forested interior in the late 1800s (Gill 1885). A few specimens were collected for museums in the early 1900s, but the species was not recorded again until 1973, when David Holyoak discovered a small pocket of birds in the hills of southern Rarotonga. This area, at the head of the Tōtoko'itu and Tūroa valleys, and two side basins off the Avanā valley has been the focus of recovery efforts for the species and became the Takitumu Conservation Area.

Both males and female kākerōri undergo the same set changes in colouration as they grow older: all yearlings are orange, with a yellow base to the dark bill; all 2-year-olds are orange, with completely dark bills; 3-year-olds are a variable 'mixed' colour, ranging from some females that are blotchy grey and orange, through to some males that are mainly grey but with a variable amount of orange feathering especially on the tail, upper back and wing coverts and about 10% of males appear entirely grey in the field; all birds 4 or more years old are entirely grey (Robertson *et al*. 1993; Zhao *et al*. 2009).

Although yearlings of both sexes bred successfully when the population was very small, nowadays most yearlings and 2-year-old kākerōri (i.e. those in orange plumage) form loose flocks on the ridge tops, away from occupied territories; however, a few join adults as 'helpers' to defend a territory and to help raise young.

Most territories are in valleys, especially those sheltered from the prevailing southeast trade winds. Adult kākerōri are strongly territorial and remain in their territories 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 creek. Replacement clutches are often laid if nests fail, but only 4% of kākerōri pairs re-nested after successfully fledging young (Saul *et al*. 1998).

The main cause of nest failures was predation by ship rats (*Rattus rattus*) and/or kiore (*Rattus exulans*), with a suspicion that karavia/ long-tailed cuckoos (*Eudynamys taitensis*) ate some eggs and nestlings. Although present deep in the forest, there is no evidence that manu kavamani/ common mynas prey on kākerōri eggs or nestlings. Female survival is lower than that of males because females incubate at night and so are vulnerable to rat predation, but the oldest colour-banded bird was a female which reached a minimum age of 24 years and 8 months.

Appendix 2. Kākerōri band combinations

Principal band combinations on the bird's right leg for each year cohort of kākerōri over the past 20 years. In some years, two different age class (right leg) combinations have been used. Each bird had a unique combination of two different colour bands on the left leg.

Before 1999, most kākerōri were banded with unique combinations of 2-3 bands (maximum of two bands per leg), but without specific year classes denoted – only four of these birds (all with 3 bands) were still alive in 2017.

In most cohorts, other combinations of bands have been used (usually as unique combinations of 2-3 bands or simple band combinations not seen for many years) when grey (4^{+}–year old) birds have been banded, and then retrospectively identified from which territory they occupy and hence which unbanded individual they had been. The number of birds alive in 2017 (or banded more recently) with cohort combinations or other combinations is given below.

WB = White above Blue. G = Green, R = Red, Y = Yellow, O = Orange, K = Pale Green, S = Sky Blue.

Year hatched	Right leg	No. banded	No. alive	Others	Others alive
1999	WB	19	3	5	0
2000	GW	17	1	3	0
2001	RW	19	2	4	1
2002	BY or BR	23	2	2	1
2003	YW or YB	34	3	3	1
2004	WG or WY	29	4	1	1
2005	RB	12	3	2	1
2006	GY or RG	30	8	4	2
2007	BO	31	7	5	1
2008	WO	30	8	9	4
2009	YR	22	9	4	2
2010	KW or WS	24	7	6	4
2011	YG	27	13	3	2
2012	BS	31	16	5	5
2013	BG	19	15	0	0
2014	RY	17	15	2	2
2015	BW	30	28	2	2
2016	WR or YW	45	45	0	0
2017	OR or YB	45	45	2	2
2018	SB or YW	39	39	0	0

Appendix 3. Annual schedule of activities

Activity	J	F	M	A	M	J	J	A	S	O	N	D
Kākerōri nesting												
Kākerōri banding												
Kākerōri census												
Main rat poisoning												
Interim poisoning												
OR												
Ecotours												
School visits												

NB : Dark shading indicates the main months for the activity, light shading indicates lesser activity or for only part of the month. The options for interim poisoning are for two rounds between the main poisoning period or for a single round.