Using genetics to save kākāpō

NZASE resource

A male walking along a track in breeding season. Jake Osborne, Flickr, CC BY-NC-SA 2.0

Kākāpō numbers have rocketed in the last seven years compared with the previous 20, helped by accurate genetic information that informs conservation decisions. NZASE Science Communicator Mike Stone investigates.

Kākāpō have the Latin name *Strigops habroptilus*, meaning striped face and soft feather. They belong to the parrot order in their own subfamily, along with kea and kākā.

Visiting parrot experts find kākāpō very unusual – they are heavy, flightless and nocturnal and reproduce by a lek system. This involves males clearing tracks between bowls they dig into the ground, then booming from an inflated throat sac, a call amplified over great distances by the bowl.

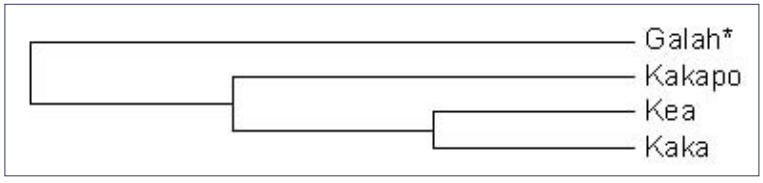
Females choose a mate based on the quality of the sound, but both sexes are polygamous. The females nest in hollow trees or under logs, incubating one to four eggs and feeding chicks for many months by themselves.

However, kākāpō only breed when rimu fruit heavily (an event called masting), every two to four years. The hungry chicks of these big birds require a lot of nutritious food – they can be fed up to 500g of rimu berries a night.

These berries provide high levels of vitamin D, of which kākāpō have very little.[1] While that may be a reason rimu is helpful, we still do not know the trigger for kākāpō breeding.

Both the birds and their nest are very smelly; however, their colouration camouflages them well, and in the presence of danger these birds freeze.

While kākāpō do climb high into trees, they cannot really fly down, at best managing a controlled plummet.[2]



Kākāpō phylogeny by Silke Steiger, Andrew Fidler and Bart Kempenaers, 2009.

Mātauranga Māori

The Māori name kākāpō means night parrot; they were also known as tarapō and tarepō.[3]

The kākāpō is regarded as a taonga species by Ngāi Tahu, and features in some of their pūrākau. Historically these manu were kept as pets but they were also hunted for their meat and for feathers, which were woven into cloaks.

The korowai worn by our flag-bearer, Beatrice Faumuina, at the 2000 Athens Olympics included kākāpō feathers.[4]

Tane Davis currently represents Ngāi Tahu in the Kākāpō Recovery Group, ensuring that mātauranga Māori is intrinsically included in management decisions. Tane says they have had to adapt their tikanga to keep the taonga alive; eg, by artificially inseminating kākāpō and separating eggs from their parents to hatch them in an incubator.

The team's desire to revert to a more natural and less intensive management brings these world views closer, according to Andrew Digby of DoC.

Ngāi Tahu are very involved in the translocations, and Tāne sees the recent move of kākāpō to Waikato as the tikanga of whāngai between Ngāi Tahu and Ngāti Korokī Kahukura, Raukawa, Ngāti Hauā, and Waikato, strengthening ties between these iwi.

The recovery vision for the species is to restore the mauri of the kākāpō by having at least 150 adult females.[5]

History

Fossils show that kākāpō were once found throughout Aotearoa New Zealand, preyed upon only by avian predators which hunt by sight. When Europeans arrived there were very few North Island kākāpō. Numbers started to decline rapidly with the European introduction of mammalian pests that hunted by smell, especially stoats.

Kākāpō completely disappeared from Te Ika-a-Māui by about 1930, but persisted longer in the wetter parts of Te Waipounamu.[2] In 1977, a

population of birds was found on Rakiura Stewart Island (numbers are disputed), but cat predation decimated these in three years.

A remnant population of 18 males was found in Fiordland and together with birds from Rakiura, the entire known population was transferred to Whenua Hou/Codfish Island. By 1995 only 51 remained and of these only 40 reproduced.[6]

Most kākāpō are found on five forested, predator-free offshore islands: Pukenui Anchor Island and Te Kākahu Chalky Island in Fiordland; Whenua Hou Codfish Island and Pearl Island near Rakiura, as well as Hauturu-o-Toi Little Barrier Island.

Anyone visiting the islands must go through a strict quarantine inspection. With 248 birds in 2023, the breeding islands (Pukenui, Whenua Hou and Te Kākahu) are almost at capacity.

Weighing scales at feeding stations help scientists monitor kākāpō remotely. From Wilderness magazine.

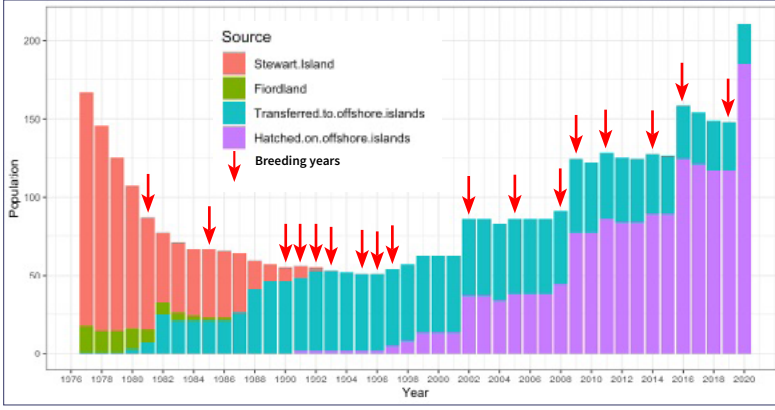
Conservation of kākāpō

Kākāpō are critically endangered. They have a small population and are subject to strong genetic drift.

When numbers were their lowest in 1995, the Kākāpō Recovery Programme began to manage kākāpō conservation with close monitoring, informed by research. It was led by the Department of Conservation (DoC) in partnership with Ngāi Tahu,[7] using both science and mātauranga Māori to bring the species back from the brink of extinction.

Kākāpō are threatened by predators, genetic inbreeding, infertility and disease. They are preyed upon by stoats, possums, cats, and brown and black rats, but translocation to predator-free islands removes this threat.

Ten young males (less valuable than females) from Whenua Hou were translocated to Maungatautari Sanctuary Mountain in 2023. Part of a project funded by the International Visitor Levy, this will take pressure off the islands ahead of future breeding seasons.



Kākāpō population since 1976, with breeding years indicated.

It is also an experiment to see if this habitat will be suitable for kākāpō. Will the predator-proof fence contain them, and will they boom there with a lower density of rimu?

When a masting year is predicted (when more than 8% of rimu tips bear fruit)[1], more volunteers are moved onto the islands to help with breeding season.

Breeding on the three islands is now tightly controlled. Carefully monitored supplementary feeding of most adults ensures the mother's weight is in the range for producing a higher proportion of female chicks.[8]

Each kākāpō is tracked by an attached transmitter, which records movement indicating foraging, nesting, and mating, and a receiver that records with whom. This makes it possible to identify the two birds who mated.

If the male is too young, too closely related, or already over-represented in the gene pool, then other more suitable sperm is collected and artificially inseminated into that female within five days. "The egg accepts the freshest sperm, so can override an unsuitable match," says DoC's Andrew Digby.

If necessary, laid eggs can be removed and incubated artificially, replaced with a warm, cheeping mimic.[9] Cameras in the nest monitor chicks remotely, and on hatching, chicks are weighed nightly to ensure they're disease-free and growing well. If not, they are hand-reared for a short while. Fledglings are checked every 2-6 weeks for five months, then every three months until they are two years old.[9]

These strategies are starting to bear fruit, as the population has grown from 124 in 2016 to 248 kākāpō in 2023 (from 50 in 1995).

Genetic diversity

With small populations, the risk of extinction is high. "Population declines are often associated with loss of genetic diversity, inbreeding and accumulation of deleterious mutations, which can lead to a reduction in fitness and subsequently contribute to extinction."[10]

A goal of conservation management is to minimise inbreeding to maintain as much genetic diversity as possible.

Bruce Robertson, of the University of Otago,

analysed kākāpō skins held in museums, collected between 1884 and 1985. He found 17 different mitochondrial haplotypes (female genetic lineages). Today's kākāpō population has just three,[11] representing a significant loss in genetic diversity.

This is due to the population passing through several genetic bottlenecks. One was about 125 years ago when mustelids were introduced,[11] and another in the early 90s when cats killed three-quarters of the population on Rakiura.

There is no genetic evidence of any earlier population bottlenecks due to hunting by Māori.[11] There is evidence that the kākāpō range contracted at this time; with seasonal pockets of hunting it is possible the birds remained locally abundant in less intensively settled areas. The genetic signature of a moderate and localised decline may have been erased by the subsequent more severe bottleneck.[10]

Many kākāpō are now closely related, and this inbreeding results in infertility. In 2016, 123 eggs were laid – 64 were infertile and 12 embryos did not survive, so 47 chicks hatched but only 36 survived to fledge.[12] This means only 29% of the eggs resulted in a surviving bird.

This low hatching success suggests that kākāpō suffer inbreeding depression and carry deleterious mutations due to genetic drift.[6]

Inbreeding may also result in susceptibility to disease. In recent years, birds have been killed by the fungal disease aspergillosis, as well as the bacterial infections erysipelas and cloacitis.[13]

Maintaining genetic diversity means knowing the pedigree of each bird and ensuring that only less related individuals mate. Until 2016, pedigrees were validated by genetic markers and microsatellite.[7] Since then, full genomes have been used.

Almost all kākāpō are descended from a small founding group transplanted from Rakiura in the 1970s and 80s. But a few are the offspring of Richard Henry, one of the males caught in Fiordland in the 1970s, and the only one of them to breed – crucial to the population's genetic diversity. He fathered three chicks, who are now all breeding.

Genomics

Between 2016 and 2018, the genome of every living kākāpō was sequenced in the Kākāpō 125+ project. Crowd funding raised $135,000 of the money for this, organised by The Genetic Rescue Foundation, a non-profit group.

Jane, a founding kākāpō from Rakiura, was chosen to have the DNA from her blood sequenced first, as the reference genome. Hers was the most expensive (half the total cost) because assembling the 20,000 base-pair sections in the right order for all 26 chromosomes is difficult, requiring 75 repeats of the process to ensure the match is correct.

Chicks can be hand-reared if needed. © Andrew Digby, DoC.

Once completed, Jane's genome acted as a roadmap for piecing together other kākāpō genomes. DNA from the rest of the kākāpō populations was kept in Aotearoa and sequenced by a new lab, New Zealand Genomics, a collaboration between three universities. Both the 2019 and 2022 cohorts have since been sequenced, at a cost of about $500 a bird.

The information was made publicly available for non-commercial and appropriate use. The approval process is overseen jointly by DoC and Ngāi Tahu.

Once the first 169 genomes were sequenced, scientists identified the genes and their functions by comparing the kākāpō sequence with that of other birds. Then they looked at the individual kākāpō sequences for some specific information:

- Is there a genetic cause for kākāpō infertility?
- What do the MHC genes tell us about kākāpō immunity to disease?
- Do the Fiordland and Rakiura kākāpō have different adaptations?
- How accurate are our kākāpō family trees?
- What are the ages of the oldest kākāpō?
- What is the viability of offspring produced by artifical insemination (AI)?
- What markers indicate inbreeding in kākāpō?

Ngā Kupu

Hononga – Connection
Huinga ira – Genome
Korowai – Cloak
Manu – Bird/s; any winged creature
Mauri – Life force, vitality, special nature
Pūpukurua – Inbreeding
Pūrākau – Ancient stories, myth/s
Taonga – Treasure, anything prized
Te Ika-a-Māui – North Island
Te Waipounamu – South Island
Whāngai – Adopt, foster, nourish.

Te Aka Māori Dictionary

- Is there a genetic basis for diseases found in kākāpō?

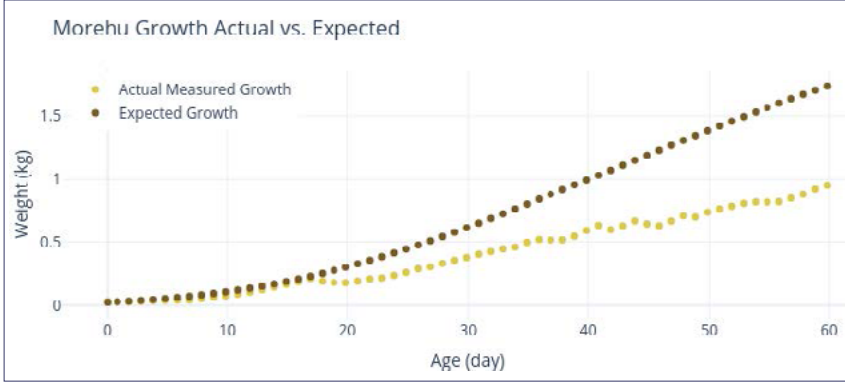
The results so far:

- The two founder populations diverged around the time Rakiura separated from the mainland, 12,000 years ago, when the sea level rose at the end of the last glaciation. This suggests it was not due to humans taking birds to Rakiura.[6]
- Rakiura kākāpō have more extended runs of homozygous alleles than those from the mainland, indicating inbreeding in the last 250 years.[6]
- More accurate information about how closely related the living kākāpō are.[7]
- Richard Henry's lineage has a few more harmful genes, but also carries values associated with higher fitness and fertility.[7]
- Some mutations associated with fertility, development and immunity have been identified.[7]
- Active management over the past 45 years has maintained both genome-wide diversity and diversity in breeding values, and hence, evolutionary potential.[6]

Since 2020, when the first research was published, this genomic information has been used to prioritise individuals for translocation, and to monitor individuals at risk of disease or poor growth. It is expected to be used to enhance strategic mate pairings and artificial insemination in the next breeding season. The genome will also provide the basis for modelling the impacts of future conservation interventions on genetic diversity.

Using genetic information to inform conservation decisions has helped to accelerate growth in the kākāpō population. There are obvious implications for other species in a similar position.

Tane Davis, Ngāi Tahu, and Fiona McKenzie, Ngāti Manuhiri, release a kākāpō. Deidre Vercoe, DoC.



Above: Growth curve of Morehu, a regularly ill chick. Expected growth is derived from average parental phenotypes. From Guhlin et al., 2022.

Below: Pukenui Anchor Island in Dusky Sound, one of the main kākāpō breeding islands. © Andrew Digby.

Endnotes

1 *NZ Geographic*, 2016, Decoding kākāpō.
2 NZ Birds Online, Kākāpō.
3 Best, 1909, Forest lore of the Māori.
4 Tipa, 2006, Kākāpō in Māori lore, *Notornis*, p. 193.
5 DoC, 2013, Kākāpō recovery, A plan for the future.
6 Dussex, N., et al., 2021, Population genomics of the critically endangered kākāpō.
7 Guhlin, J., et al., 2022, Species-wide genomics of kākāpō provides transformational tools to accelerate recovery.
8 *Wikipedia*, 2023, Kākāpō.
9 Natural History Museum, NZ's quirky kākāpō are pulled back from the edge of extinction.
10 Dussex, N. et al., 2018, Full mitogenomes in the critically endangered kākāpō..., *Genes*.
11 Bergner, et al., 2016, European colonization, not Polynesian arrival, impacted population size and genetic diversity in the critically endangered New Zealand kākāpō.
12 Hall, A, 2016, You've got email, *Wilderness magazine*.
13 Young, J., 2023, *Genomes at work*. Triple Helix, Owaka.

Other resources

DoC, Kākāpō male 'booms' recording. (MP3, 2m)
Thomas Lebas, Kākāpō infographic posters.