Population Survey for North Island Brown Kiwi (*Apteryx mantelli*) on Kawau Island

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Final report

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Summary and Purpose

This report presents the results of a comprehensive mark-recapture dog survey of the North Island brown kiwi (*Apteryx mantelli*) population on Kawau Island (Te Kawau Tūmaro-o-Toi), undertaken between January and March 2025. It builds upon historical listening surveys conducted in 1993, 2002, 2005, and 2012, as well as ARD surveys completed in 2015 – 2018 (Department of Conservation, 1993; Baird, et al., 2002; Baird & Griffiths, 2005). Additionally, kiwi were found by a trained dog who was also searching for pāteke in 2012, and a thermal camera survey was conducted in 2019. All survey data collectively indicated a persistent but poorly understood kiwi presence on the island. The mark-recapture dog survey completed in 2025 provides the first detailed health and demographic assessment of this population. The primary aim of this survey was to determine population structure, health condition, sex ratio, and encounter rates using an interim certified kiwi detection dog, with the broader goal of informing future kiwi management strategies.

Fifty-six kiwi were detected across three separate survey trips, with 51 individuals physically handled. There were no recaptures during the survey periods. The survey revealed a population largely composed of adults in moderate to poor condition and a complete absence of juveniles or chicks in the subset of the population sampled. These findings suggest low reproductive success and minimal recruitment in the 2024/25 season, and likely for at least several years prior. The low body condition observed across the island, combined with dry environmental conditions as well as habitat degradation may be contributing constraints to population resilience.

The population's origins are believed to trace back to a small number of birds translocated from Hokianga in the 1860s by Governor Grey. Potential supplementation from the Coromandel in the 1950's or 60s have been suggested anecdotally. This restricted founder history raises the likelihood of a genetic bottleneck. Genetic samples collected during this survey confirmed that the Kawau population has very low genetic diversity, with many individuals sampled closely related (Figure 1). While some unique genetic traits were found, the population's limited genetic variation suggests long-term isolation and potential inbreeding risk. These findings mean that targeted genetic rescue may be required, via translocations onto Kawau. At the same time, carefully managed translocations off the island should also be considered, both to safeguard some of the unique alleles present in this population and to create space for new founders to establish territories. In this way, Kawau could play a dual role: both benefitting from new genetic input and serving as a source for supplementing mainland populations (e.g. Hokianga region).

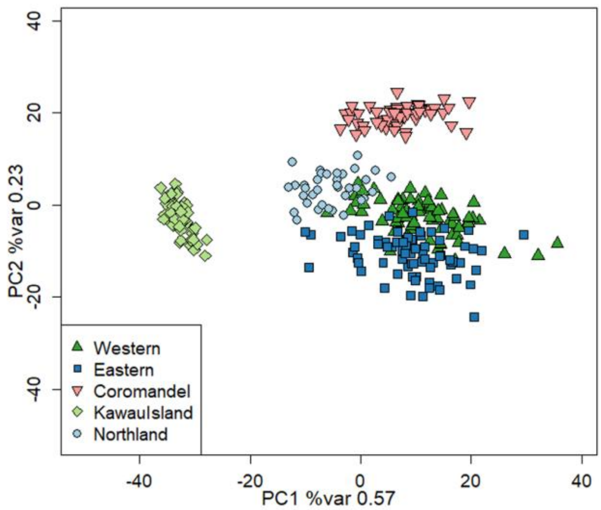


Figure 1. Principal component analysis plot of the Kawau Island samples with other NIB Kiwi samples from different populations (EcoGene, 2025)

The findings from this survey raise important questions about the long-term sustainability of the Kawau kiwi population in the face of climatic change, habitat degradation, and genetic isolation. Of particular interest is that Kawau is home to wallabies, and this may have affected the kiwi population over time. Regular monitoring, improved habitat management (especially wallaby control), and integrated genetic planning are either currently underway or urgently recommended. By addressing these biological and ecological factors together, we will be better positioned to safeguard this population and leverage its potential role in broader species recovery goals.

Introduction

Kawau Island (Te Kawau Tūmaro-o-Toi) is located in the Hauraki Gulf, approximately 1,500 - 2,300m off the mainland of Aotearoa, New Zealand. The island measures around 2,000ha (20km^2). Historically modified and now heavily browsed by wallabies, it contains remnant native forest and is home to a population of North Island Brown Kiwi (*Apteryx mantelli*). Kiwi are believed to have first been introduced to Kawau in the 1860's by Governor George Grey, who owned the island from 1862 for 25 years. It is believed that the kiwi were gifted by Judge Frederick Maning and were sourced from the Hokianga in Northland although some reports on the island indicate that some kiwi with Coromandel origins may have been introduced in the 1950's or 1960's - the accuracy of this is unknown. Genetic testing confirms that Kawau kiwi are genetically distinct from other North Island brown kiwi populations, though with some signs of possible past introductions. However, the population is genetically clustered and separate, supporting the view that they have been isolated for a long time.

Historical information available about the Kawau Island kiwi population, includes listening surveys undertaken in 1993, 2002, 2005 and 2012. The 1993 survey (Figure 2) was based on 28 listening sites and mapped adult territories. Two nights of listening data were collected and during that time, 43 kiwi (32 males and 11 females) were mapped over the area covered by the sites. The skewed sex ratio may have been due to higher call rates and better call coverage from males, leading to a higher detectability. The 2002, 2005 and 2012 call surveys did not map adult territories. In 2015 to 2018 ARD's were placed at 3 to 4 repeated sites annually. The outcomes of these showed a stable/slightly increasing trend in kiwi calls, however there was a significant drop in rates compared to the call count surveys. A further kiwi call count survey undertaken in 2025 showed results broadly consistent with earlier patterns, indicating increases in relative abundance in some areas of the island. As with previous call surveys, these results must be interpreted cautiously, as call counts provide an index of relative abundance of calling adults rather than an estimate of absolute population size and are influenced by factors such as calling behaviour, detectability, and survey conditions. In 2019 a survey was completed using thermal imaging which suggested a population larger than 450 kiwi, the methodology was however not validated and therefore not sufficiently repeatable, this means it is therefore not to be relied upon for management purposes. The outcomes of the thermal imagery survey was also at odds with previous survey outcomes. It is important to note that kiwi call count surveys only give a measure of relative abundance of calling adults, not absolute abundance. However, a 10-fold increase of the estimated population size was reported between 2002 and 2019, with no increase in the mean number of kiwi calls heard, which seems unlikely. Therefore, the need for a more informative survey method was proposed in September 2023 and implemented in 2025.

A mark-recapture analysis of the Kawau kiwi population was undertaken in February - April 2025 (under Save the Kiwi's Wildlife Authority 118001-FAU). A kiwi dog and her handler captured 51 individual kiwi from across the island, over three island visits spread out across the three-month period. The survey was aimed to gather baseline data on the current kiwi population across the island, the population structure, and health. This method complements historical call count surveys and provides more direct insight into demographic and health parameters, which cannot be obtained through call count or territory mapping. In addition, dog surveys can provide an indication of population density. When repeating surveys in subsequent years, the data can be used to build a clearer picture of population structure, recruitment and health.

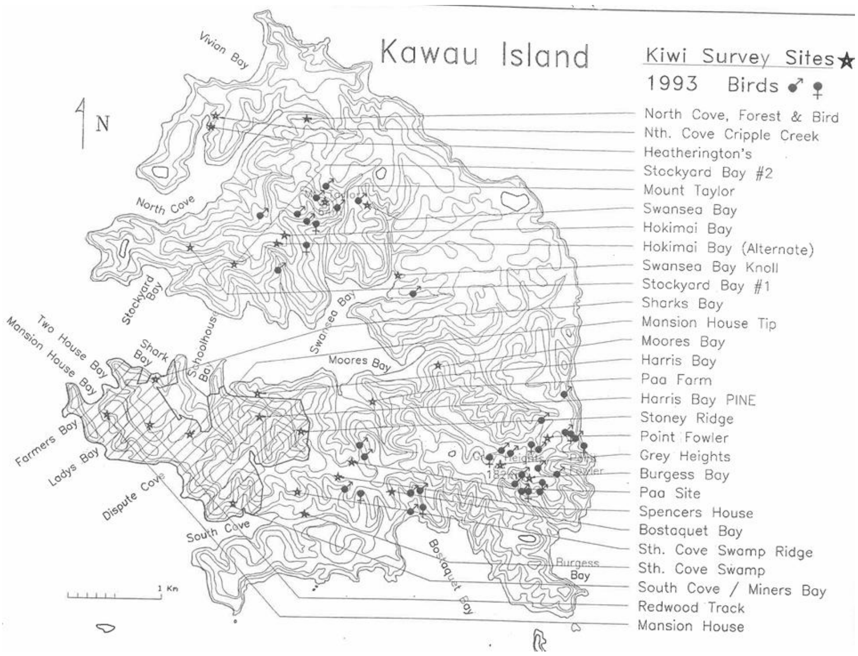


Figure 2: Map of Kawau Island Kiwi Survey Sites 1993 – showing male and female kiwi sites (Department of Conservation, 1993)

Background Dog Survey

Previous kiwi listening surveys on Kawau indicated the presence of paired kiwi, but demographic structure, reproductive success and health condition of the birds remained unknown. In 2024, a predator detection dog survey, undertaken by Miriam Ritchie and Brad Windust and their trained dogs, found no evidence of stoats on Kawau. However, species on the island remain vulnerable to predation from domestic dogs and stoats, and the habitat suffers significant ecological pressure from wallabies, which heavily browse the understorey, potentially limiting food availability for kiwi.

Understanding the drivers of population health and sustainability requires a methodology capable of directly detecting individual birds, evaluating the condition of the birds and enabling genetic sampling. Conservation dogs are used in mark-recapture studies, and this method was deemed the most effective approach for an updated population survey.

Methods

Between 14 January and 28 March 2025, 14 dog handler days were completed over three trips (Figure 3) using certified kiwi dog *Kimihia* (German Shorthaired Pointer with interim certification) with her highly experienced handler Tom Donovan. Due to her interim certification status, the dog was worked on a long lead. Start time, search time and end time were recorded for each day. A GPS was used to record the distance the handler travelled while searching and the waypoint location for each kiwi was noted, although pairs roosting together were recorded as a single encounter. Two measurements of kiwi encounter rates were recorded: 1. Kiwi by unit distance and 2. Kiwi by unit time.

Initially a grid search pattern was attempted on search lines 80 – 100m apart, however due to the dry conditions in the lead up to the survey (NIWA, 2025), it was quickly established that kiwi were absent on ridges and hills. Gullies were the only sites where kiwi were found. Based on this, the decision was made to focus search efforts in gullies instead to ensure sufficient sample size was acquired. Weather conditions and ground moisture levels were recorded as these can have an impact on kiwi detection rates.

For each kiwi located and handled, biometric data including sex, weight, bill length, and body condition score were recorded as per Best Practice procedures (Colbourne, et al., 2020). Roost type and location were noted; pin feathers were collected for DNA analysis and unmarked individuals had a microchip inserted at capture. This allows for future dog surveys to measure recapture rates of known individuals. Additionally, extra notes were collected, such as parasite burden (some parasites were collected for further identification if required), presence of brood patches and any distinctive external markers (e.g., white feathers).

Results

A total of 56 kiwi were located and 51 of these were successfully caught (with others out of reach of the handlers - e.g. roosting in deep burrows). None of the kiwi found had existing microchips and therefore all kiwi handled had a microchip inserted. None of the marked birds were caught more than once this season. The mean daily capture rate was 3.6 kiwi.

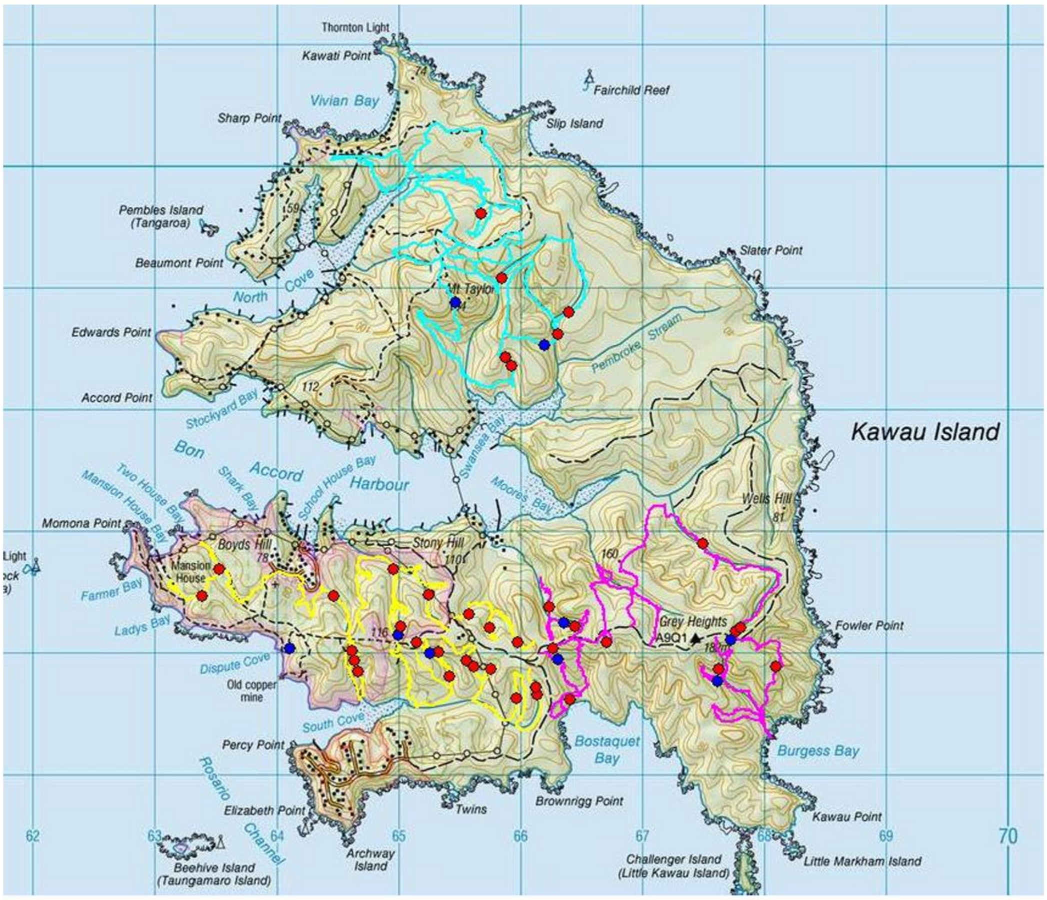


Figure 3: Map of Kawau Island demonstrating survey trips and kiwi encounters. Trip 1 = light blue; Trip 2 = Yellow; Trip 3 = Pink. Red dots indicate a single bird encounter and blue indicates a pair.

Sex distribution

The 51 birds handled provided a balanced sex ratio (Table 1) with 26 classed as male, 23 as female and a further 2 were left as "undetermined". Morphological sexing was occasionally inconclusive due to unusually short bill lengths and low body weight. DNA testing confirmed the sex of the undetermined individuals to be male.

*Table 1: Number of North Island brown kiwi (Apteryx mantelli) handled on Kawau Island by sex. *indicates DNA testing confirmed these to be male.*

	Male	Female	Undetermined	Not handled
2025	26	23	2*	5

Age structure

Of the 51 kiwi handled, 48 of these were classified as adult birds and the remaining three were classified as subadults (Figure 4). There was a notable absence of chicks or juveniles during the survey. Although on 30 January 2025 a small kiwi was found collapsed, emaciated and dehydrated. It was taken to the New Zealand Centre for Conservation Medicine at Auckland Zoo, where it subsequently died. The post-mortem results noted a weight of 650gr, bill length 79mm and tarsus length 70mm. No external injuries were noted. A fungal pneumonia was identified, likely secondary to severe immunocompromise as a result of dehydration and emaciation. Another dead kiwi was found on 28 March 2025 - the carcass was badly decomposed, limiting post-mortem assessments, but the bird appeared to be in poor condition.

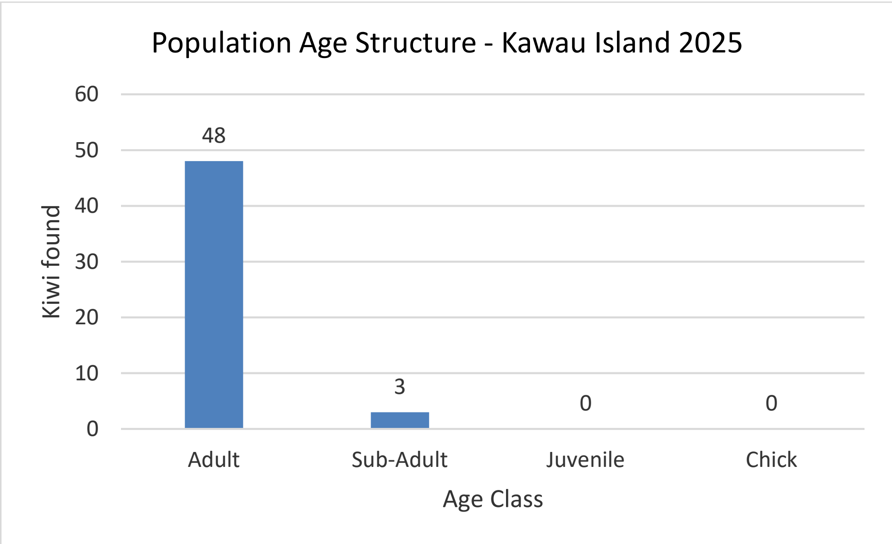


Figure 4: Population Age Class Structure for kiwi during Kawau Island dog survey 2025

Body Condition

Most of the birds were classed as being in "Moderate" to "Poor" condition (Table 2 and Figure 5) with only a few assessed to be in "Good" condition. Those in "Poor" condition appeared to be dehydrated and underweight (similar to the individual found on 30 January 2025). Two males showed signs of possible brood patches. No chicks or juveniles were located, likely due to poor breeding success during the hot, dry summer.

Table 2: Kiwi Body Condition Scale

Scale Descriptor	Qualifiers
Poor	Kiwi has a sharp and pronounced backbone, washboard ribs and lack of fat covering on thighs.
Moderate	Kiwi has a backbone that is still obvious, but not sharp and a small covering on the ribs.
Good	Falls between moderate and excellent respectively.
Excellent	Kiwi has a difficult-to-find backbone, fat covering over ribs and meaty thighs.

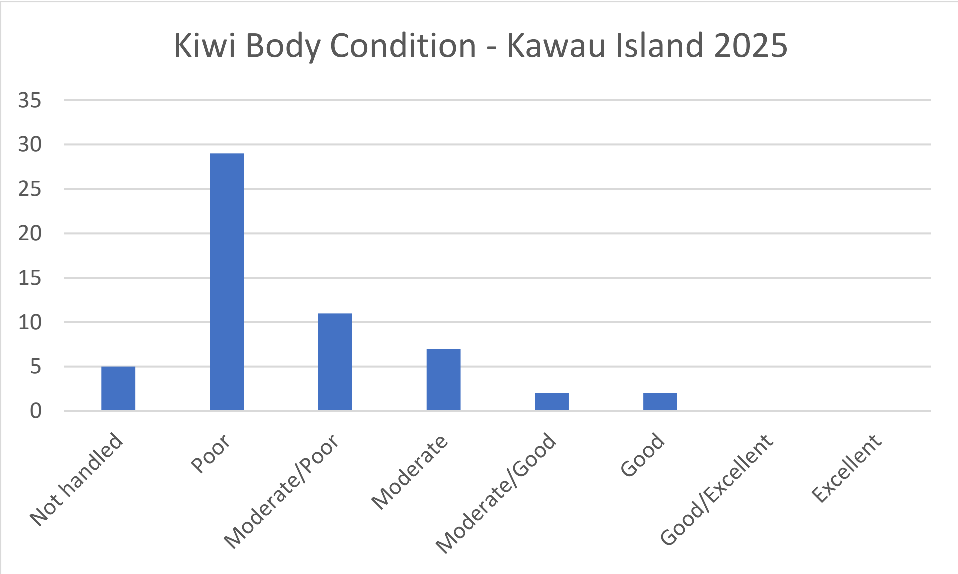


Figure 5: Condition Scaling of North Island Brown Kiwi (Apteryx mantelli) handled on Kawau during 2025 Dog Survey

Parasite burden

Ticks (and some mites/lice) were observed on several individuals. Samples of ticks were collected and preserved for species identification purposes if requested.

Encounter Rates

Across all trips, the combined search effort totalled 50.64km and 48.95 hours. Encounter rates were highest in the Southwest survey zone and lowest in the Northern survey zone. The average encounter rate for kiwi per survey are noted in table 3 and figure 6 below.

Table 3: Kiwi encounter rates for Kawau Island dog survey 2025

Survey Trip	Site location	Kiwi finds/hr	Kiwi finds/km
1	Northern	0.46	0.43
2	Southwest	1.29	1.24
3	Southeast	0.96	0.97
Aggregated		0.90	0.87

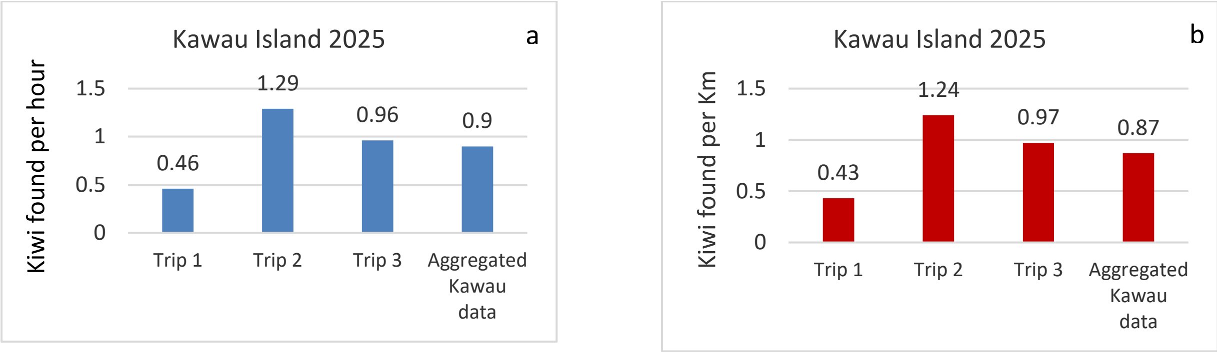


Figure 6: Kiwi encounter rate during Kawau Island Dog Survey 2025. Rates noted per hour (a) and per kilometre (b).

Population estimate

Without previous marked kiwi to include in the mark-recapture survey, it is impossible to apply the Lincoln-Peterson index to estimate population size, which is the most appropriate method for analysing closed populations like these. However, in Northland population rates are based on 1 pair per 3 to 4ha which in the case of Kawau would mean the carrying capacity for the island would be around 500 - 666 kiwi pairs. The encounter rates during the 2025 dog survey demonstrate that the kiwi population is still very low on Kawau - however this may have been due to the dry conditions as well as the fact that birds were burrowing down very deep. Subsequent mark-recapture surveys will be able to benefit from the current survey's microchipped kiwi to help estimate the population more accurately.

Table 2: Summary of catching data from kiwi dog survey completed on Kawau Island.

	Physical captures of kiwi	Unique kiwi located	Microchip detected	Dog Days worked	Kiwi caught per day	Percentage are founders	Estimated currently living founders	Estimated minimum nr of kiwi on Kawau (based on dog survey)
2025	51	56	0	14	3.6	Unknown	Unknown	TBD

Genetic Considerations

The origin of the Kawau Island kiwi population is historically traced to a small founder group (the exact number is unknown), likely introduced from the Hokianga region between 1862 and 1887. Anecdotal reports suggest additional introductions from Coromandel in the mid-20th century, although this remains unverified.

In comparing Kawau Island's kiwi population growth to other similarly sized islands, it is reasonable to assume that, if conditions were favourable, a population founded in the 1860s should now number well over a thousand individuals. For example, Ponui Island, which is approximately 1,800 hectares in size, supports a kiwi population estimated between 1,500 and 2,000 birds, this population was established from 14 founders which were brought to the island in 1964. Kawau Island, at roughly 2,000 hectares, has had kiwi present for over 140 years, yet one of the historical surveys completed in 2002 reported only 42 individuals.

The restricted number of founding individuals, the geographic isolation of the island and the direct and indirect impact of other species (e.g., wallabies and weka) on the kiwi population may have caused an increase in the likelihood of a genetic bottleneck, which in turn may reduce genetic diversity and limit adaptive potential. Additionally, the extensive browsing of the understorey and ground layer by wallabies may have reduced leaf litter and associated invertebrates to the point that it became non-sustainable for insectivorous birds such as kiwi to feed. This issue would be more pronounced in kiwi chicks as they have much shorter bills, so less ability to probe for food.

Pin feathers collected during this survey were analysed by EcoGene in 2025. Results confirmed that the Kawau population has markedly lower genetic diversity than other North Island brown kiwi populations. Many DNA markers that usually vary across individuals were uniform in Kawau birds, and several were highly related, confirming inbreeding risk. A few alleles were unique to Kawau, which suggests long-term isolation, but the overall diversity was low (EcoGene, 2025). Inbreeding depression, which in general could manifest as reduced fertility, poor condition, or developmental abnormalities - may be visible in this population since this survey did detect a lack of breeding/ chick recruitment as well as overall condition scores being low - although the cause of this could have been environmental rather than genetic.

The genetic analysis confirm that genetic rescue should be considered to safeguard the long-term viability of this population. Introducing birds from other source populations (e.g., from Hokianga or another Northland population) can help to enhance heterozygosity. This should be completed as soon as possible post key pest eradication work. To create opportunities for new founders to establish territories, and to retain some of the unique alleles present on the island, a proportion of birds could be translocated off Kawau. This would reduce density pressures, capture unique genetics for integration elsewhere, and complement the genetic rescue of birds brought onto Kawau. With this approach, the island has the opportunity to function as an active kōhanga site – both preserving its distinctive lineage and supporting broader North Island brown kiwi recovery.

Because of the population's tight genetic clustering, future monitoring should continue to include genetic sampling to measure whether interventions proposed above improve diversity over time.

Discussion

Population Health and Structure

The 2025 dog survey showed a kiwi population composed almost entirely of adults, with no juveniles or chicks detected. This suggests poor breeding success in the 2024/25 season (and potentially prior). This may be related to dry conditions limiting food supply; however, it could also indicate a general population collapse. Most birds were in moderate or poor condition, which may also reduce fertility and nesting success. A small kiwi was found in January 2025 and subsequently died while receiving veterinary care. Upon post-mortem it was diagnosed with fungal pneumonia - likely as an outcome of the stress associated with its emaciated and dehydrated state. Additionally, another deceased kiwi was found on the last day of the dog survey in March 2025. The find was reported to DOC, and the post-mortem results indicated the bird had a poor body condition. The genetic findings reinforce the concerns about sustainability. Low genetic diversity may reduce fertility, survival and adaptability, potentially contributing to the lack of chick recruitment observed in this survey. The combination of poor demographic recruitment and confirmed genetic isolation highlights the importance of acting promptly to both import and export birds as part of a coordinated genetic management strategy.

Population Limiting Factors

Prolonged dry summers may limit carrying capacity through reduced invertebrate availability and dehydration stress. Additionally, wallaby browsing has resulted in a sparse understorey, reducing habitat complexity and food availability for kiwi – similar has been observed at Taranga Island where kiore were found to be suppressing kiwi pukupuku (*Apteryx owenii*). Further pressures on the kiwi population could be from competition and chick predation as a result of the large resident weka population (Shaw & Pierce, 2022). In addition to these, dogs remain a risk to adult kiwi survival and the ability for stoats to access the island brings with it risks to any potential chicks which may hatch in a season. In addition to habitat degradation and predation risk, wallabies may pose an indirect but significant disease risk to kiwi.

Environmental and Climatic Stressors

The 2024/25 summer season was exceptionally dry, with below-average rainfall recorded across the Hauraki Gulf region (NIWA, 2025). Kiwi are particularly vulnerable to prolonged dry periods due to their reliance on moist soil for invertebrate foraging and their limited physiological mechanisms for conserving water. During this survey, several birds appeared dehydrated and underweight, and no chicks or juveniles were detected. This aligns with known impacts of drought on breeding productivity and chick survival in other kiwi populations.

Dehydration stress and food scarcity likely contributed to poor body condition scores and may have resulted in nest abandonment, chick mortality, or complete breeding failure. During the time this survey was undertaken (January - March) it is not uncommon to find kiwi in below average condition in other areas (e.g. Northland), as a direct result of breeding. This is especially true following a second or at times third clutch. There was no direct evidence of breeding found via chicks or juveniles, and little sign of brood patches on males. The death of a chick diagnosed with fungal pneumonia may further suggest compromised immune function due to stress. Ongoing climatic variability is a growing risk to this population's viability. Monitoring of soil moisture, invertebrate abundance, and nest success in future seasons is recommended to quantify and respond to these pressures.

Habitat Degradation

Kawau Island's ecosystem is severely impacted by browsing pressure from introduced wallabies, which has resulted in a sparse and degraded understorey. This simplification of habitat structure limits invertebrate diversity and density - reducing food availability for kiwi - and decreases cover for nesting and chick concealment.

Although this survey did not quantify habitat condition directly, anecdotal observations during searches suggest that gullies offered the only viable habitat patches for kiwi. Ridges and hill slopes were largely devoid of kiwi signs, possibly reflecting habitat unsuitability due to dryness and low food availability.

It would be useful to complete a formal ecological assessment of kiwi habitat quality across Kawau Island, focusing on invertebrate surveys to evaluate food resources as well as understorey vegetation surveys to assess habitat recovery post-wallaby control, this could line up with the BFA Ecosystem Monitoring project already underway. This would provide essential baseline data for evaluating the impact of ongoing wallaby management and guiding habitat restoration priorities.

Demographic Modelling Potential

While this survey generated valuable encounter rate and sex ratio data, population size remains uncertain. The absence of previously microchipped birds means that recapture modelling could not be applied this season. However, the systematic methodology and GPS-tracked effort across 50.64 km and 48.95 hours provide a solid foundation for future mark-recapture analysis.

We recommend the use of the Lincoln-Petersen method (or more robust closed population models) in subsequent surveys, assuming known individuals are detected. This would allow for estimation of population size and survival rates. Furthermore, a projection model incorporating age class structure, breeding success, and mortality data could help forecast population trends under different environmental and management scenarios.

Health Observations and Parasite Load

The 2025 survey offered a rare opportunity to collect direct health data from 51 kiwi. Most birds were in moderate to poor body condition, and several were underweight. While no birds exhibited obvious skeletal deformities or plumage anomalies, one severely dehydrated and emaciated kiwi and one dead kiwi were found.

Ticks were commonly observed, with specimens collected for identification. Although tick presence is normal, excessive burden may indicate poor health or environmental imbalance. We recommend a health surveillance programme is integrated during subsequent mark-recapture surveys.

Beyond external parasites, disease risks must also be considered. *Toxoplasma gondii* has been confirmed as a cause of kiwi death in other regions of New Zealand (Taylor, et al., 2023; Howe, et al., 2014). Given the presence of cats on Kawau, which are known carriers and environmental spreaders of this parasite (Bowater, et al., 2023; Yang, et al., 2023), toxoplasmosis should be considered a possible contributing factor to poor body condition and mortality observed in this survey.

Predator Risk Assessment

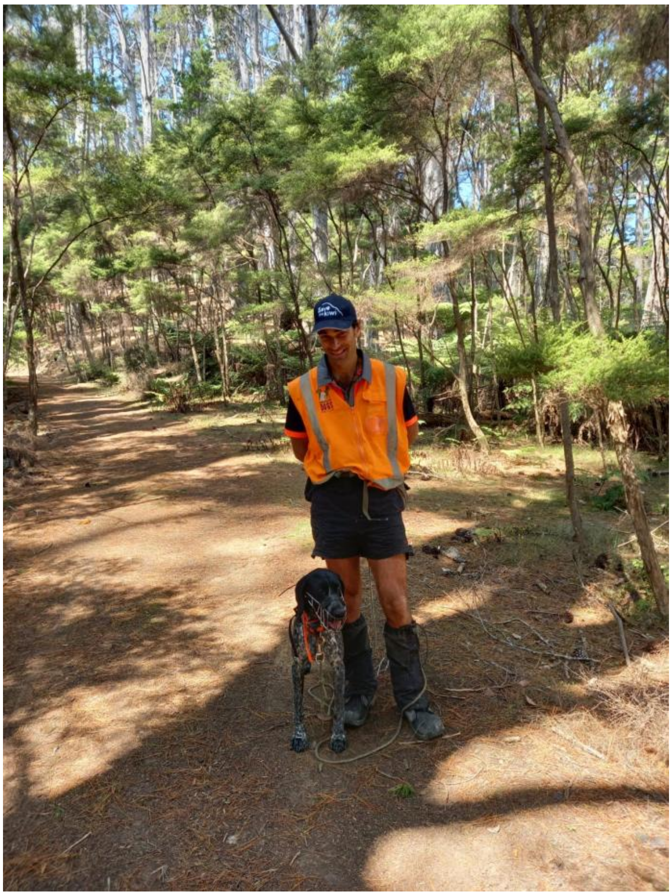
While stoats were not detected in the 2024 predator detection dog survey, dogs remain a serious risk to kiwi on Kawau Island. A passive surveillance system (e.g., camera traps) should be maintained to monitor direct impacts of predators on kiwi. One of the two dead kiwi recovered during this survey had signs which may be consistent with a possible dog attack (post-mortem pending). Kawau Island's proximity to the mainland, private land ownership, and visitor access all elevate the risk of accidental or deliberate dog incursions. We recommend a review of signage at all public access points alerting dog owners to kiwi presence as well as the exploration of regulatory protection or dog-free zoning, and/or dedicated dog exercise areas which present the lowest risk to kiwi.

Conclusion

The 2025 survey confirms that a relatively dense in some areas (e.g. Valleys – which were targeted for the survey), overall, the island has a much lower density than compared to most islands which contain kiwi. This indicates that a potentially vulnerable population of kiwi exists on Kawau Island. Despite high encounter rates, the absence of young birds and the poor condition of adults suggest breeding success was low or absent in the previous season. Climatic variability, habitat degradation, and possible dog attacks are the primary risks to the sustainability of this population. Further monitoring, predator control and education (particularly for dogs) are recommended. In addition to ecological pressures, the population's genetic health is poor, with very low diversity and high relatedness confirmed. Without intervention, these genetic constraints could compound the effects of habitat degradation and climate stress, accelerating decline. Future management will need to weigh habitat recovery alongside a dual genetic strategy: bringing in new founders to boost diversity while translocating some existing birds off the island to capture unique alleles and make space for those new founders to contribute effectively.

Acknowledgements

Auckland Council provided funding for this survey and subsequent DNA testing. Save the Kiwi provided training. Special thanks to Ngāti Manuhiri, Tom Donovan, Karina Donovan, Jimi Angel Donovan, Emma Craig, Lisa Tolich, Sabine Melzer, Thomas Hynes, Jon Bilger, Kirstie Inglis and Hinrich Voges for their efforts in the field. To EcoGene for their excellent customer services and data analysis. Last, but not least, a massive thank you to Kimihia, without whom we would not have been able to find any kiwi - keep following your nose!



Kimihia and her handler Tom Donovan

Recommendations

1. Reinstate regular ARD call surveys for island-wide presence/absence data
2. Complete further mark-recapture surveys in 2027 and 2029 (Save the Kiwi's Wildlife Authority expires on 12 January 2030)
3. Use genetic results to guide a dual translocation strategy: a) introduce new founders onto Kawau to increase genetic diversity, and b) move some Kawau birds off-island to safeguard their unique alleles and create space for new founders.
4. Integrate health and habitat monitoring (soil moisture, invertebrate abundance and nest success) into future survey efforts
5. Improve signage and visitor awareness of kiwi and dog risks
6. Complete a formal ecological assessment of kiwi habitat quality across Kawau Island
7. Gather information around the original founder population size and possible additions of other region's taxa in subsequent years
8. Incorporate disease surveillance into future health monitoring (i.e., toxoplasmosis screening)

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Appendix 1: EcoGene Kiwi Genotyping Results Report

Kiwi Genotyping Results Report

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Save the Kiwi
[redacted]

Samples

Fifty-three packets of pin feathers from North Island Brown kiwi (51 from Kawau Island, two from Trounson) were delivered to EcoGene® for genotyping, sex testing and relatedness analysis.

Sample Receipt Date: 07/05/2025

Test Date (first step of processing): 27/05/2025

Project Summary

DNA was extracted from the swabs using readymade reagents from the Qiagen® QIAamp 96 DNA QIAcube HT Kit following the manufacturer's instructions.

Sex determination was undertaken by PCR amplification of a sex specific region using the primers Z37BF and Z37BR by Dawson *et al.* (2015). Genotyping was performed by amplifying 21 microsatellite markers that had been previously developed (Jensen *et al.*, 2008; Ramstad *et al.*, 2010; Shepherd and Lambert, 2006), optimised, and multiplexed (Ramón-Laca *et al.*, 2018).

A subset of amplicons were visualised under ultraviolet (UV) light using GelRed™ stained agarose gels. Resulting DNA fragments were run on a 3500xL Genetic Analyser (Applied Biosystems by ThermoFisher Scientific) and fragment sizes were scored using GeneMapper v 6.0 (Applied Biosystems by ThermoFisher Scientific).

Resulting genotyping data was analysed for basic descriptive statistics to assess genetic diversity and other measures of the Kawau Island population and in relation to samples from other North Island Brown (NIB) kiwi populations from Ramón-Laca *et al.*, 2018. This included the number of alleles found, observed and expected heterozygosity, detection of any private alleles in the Kawau Island samples, and allelic richness. The latter analysis was conducted using the PopGenReport package (Adamack and Gruber, 2014) with R software (R Core Team, 2024) within R studio (Posit team, 2024), with the remaining analyses using GenAlEx v. 6.503 (Peakall and Smouse, 2012).

Pairwise relatedness of these samples was also undertaken using multiple estimators tested using the 'related' package (Pew *et al.*, 2015) with R software (R Core Team, 2024) and R studio (Posit team, 2024). A Principal Component Analysis (PCA) was performed using allele frequency estimates drawn from each of the population datasets to explore genetic similarity using GenePlots (McMillan and Fewster, 2017). Using the other NIB sample groups as possible reference or source populations, pairwise comparisons (using genotype probabilities)

Results apply to samples as received. This results report may not be reproduced except in full.

were performed and visualised, again using GenePlots (McMillan and Fewster, 2017), to explore how the Kawau Island samples may fit with the other NIB groups.

Results

Of the 53 samples tested, 52 produced sex test results and full genetic profiles at all markers tested, with a single sample (S1489_16) failing to generate a consensus genotype at one marker (refer to the Appendix for sample genotypes and sex test results). Summary statistics of the markers tested in the Kawau Island samples alongside other NIB samples are described in Table 1. In the Kawau Island samples (S1489_01 – S1489_51) five markers were monomorphic (KMS7R, KMS37, Aptowe29, Apt37, Aptowe23), where only a single allele was recorded in this population. Of these five monomorphic markers, Aptowe23 was found to be monomorphic in all other NIB populations that had comparative data. This indicates that this marker may not be suitable for NIB kiwi. The four other markers are only monomorphic in Kawau Island samples, indicating a lower level of genetic diversity in this population. This is further evidenced by the number of alleles detected per marker and allelic richness within the Kawau Island compared to other population data. When excluding Aptowe23, the Kawau Island population shows only one or two alleles at over half of the markers tested (N: 12/21). Allelic richness (a standardised measure to compare alleles per marker across different groups with varying sample numbers) was lower in Kawau Island for the majority of markers compared to other NIB populations (Table 1). Average heterozygosity (a measure of how often two different alleles are found at the markers tested, indicating how many different alleles are present) rates are also lower in the Kawau Island population compared to all other comparable NIB populations (Table 1). While some private alleles (alleles observed in one population and absent/not observed in other populations) in the Kawau Island population were observed, this was less than at other populations (Table 1), some of which were represented by less samples than Kawau Island.

Table 1. Population dataset information for Kawau Island and the average of other comparable NIB populations (excluding Aptowe23), including average number of alleles observed per marker (Na), average allelic richness (AR), private alleles (Pa), observed heterozygosity (Ho) and unbiased expected Heterozygosity (uHe).

Sample population	Na	AR	Pa	Ho	uHe
Kawau Island	2.5	2.5	3	0.38	0.37
Other NIB	4.4 – 6.8	4.3 – 5.9	6 - 25	0.47 – 0.51	0.52 – 0.56

Pairwise relatedness assessments were undertaken using four different estimation methods for the Kawau Island samples (monomorphic markers were removed for this testing). While specific relationship types have not been estimated here (e.g. parent-offspring), pairs of related individuals are indicated in Figure 1. Relatedness in Figure 1 is indicated between a pair that exhibited ≥0.5 in three or more of the estimators used. Given the comparatively low levels of genetic diversity in the Kawau Island population, the reported relatedness here is conservative, with only high relatedness levels reported. There are likely other close relationships, as well as lesser relatedness pairings (e.g. half-siblings), among these samples that are not indicated here. To confidently identify these relationships, further analyses are needed in order to account for the low genetic diversity of this population.

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Report Reference: S1489A
Report Date: 20 August 2025
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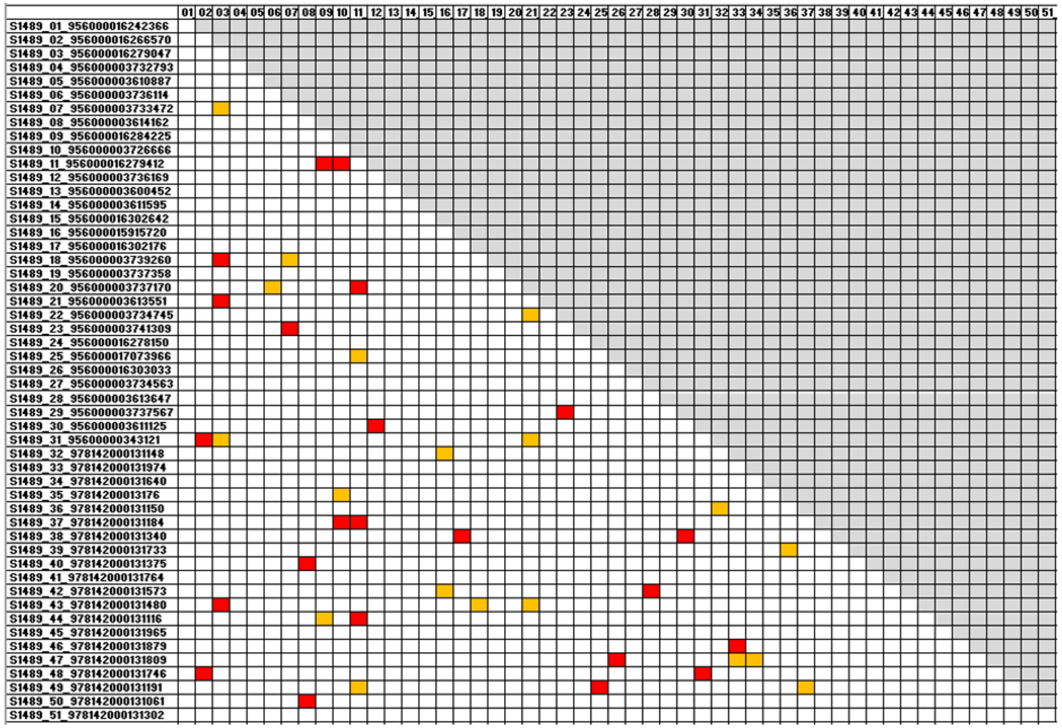

Figure 1. Pairwise relatedness matrix indicating the most closely related pairs of the Kawau Island samples (note that other related pairs beyond what is reported here are expected, refer to Results section). Red indicates three out of four relatedness estimators with coefficients of ≥0.5, with orange indicating two out of four estimators, indicating relatedness between those sample pairs. Full identification number and barcode per sample on the left, with only the sample ID number on the top for ease of viewing (e.g. "S1489_01_956000016242366", left hand side and "01" on the top are the same sample).

Results apply to samples as received. This results report may not be reproduced except in full.

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A principal component analysis (PCA) was performed using the Kawau Island samples and other comparable NIB population samples (Figure 2). Here points (samples) within close groupings indicate greater similarity to one another than to groups and sample points that are farther apart. This analysis showed a tight clustering of all the Kawau Island samples together, separate from each of the other NIB populations (Figure 2). When using GenePlots to investigate assigning, or finding the best population fit, for Kawau Island samples it was clear that Kawau Island samples could be excluded from the Coromandel group (plot not shown, and please note the Coromandel group here is only a subset of the Coromandel population and may not be entirely representative). Performing the same analysis using all other possible reference population combinations did not demonstrate a clear best fit reference population for Kawau Island (when employing the exclusion principle of McMillan and Fewster, 2017). For example, when using Northland and Eastern groups as reference populations, there are some Kawau Island samples that fit to each population and some that do not fit with either (Figure 3). The NIB PCA (Figure 2) illustrates that there is some overlap and/or close clustering between the Northland, Eastern and Western population samples, indicating that these populations are not obviously distinct, perhaps through similar founding source populations, modern translocations of individuals, or more recent/limited isolation for example. Whereas the Kawau Island samples grouped closely together and did not exhibit overlap with other population samples. While some Kawau Island samples fit with other reference populations when compared via GenePlots, this was not the majority of samples, and these samples may indicate translocated individuals or close relatives of translocated individuals.

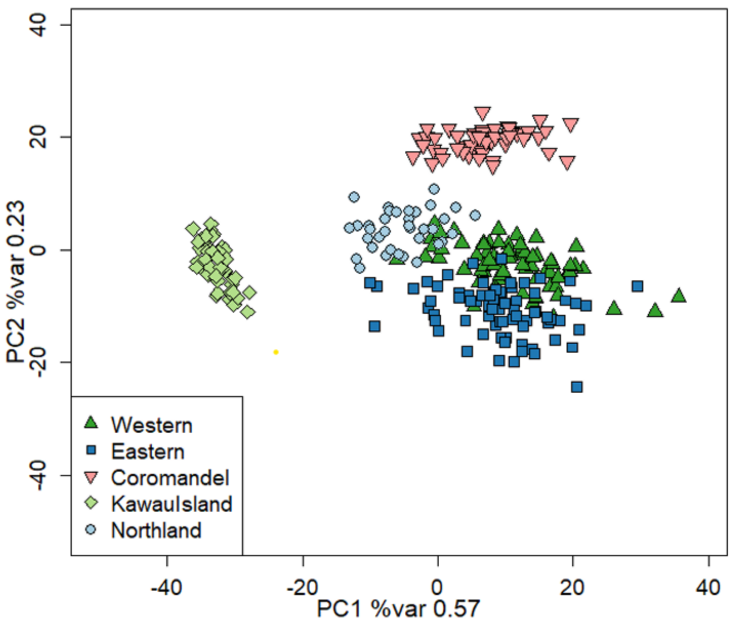

Figure 2. Principal component analysis plot of the Kawau Island samples with other NIB samples from different populations.

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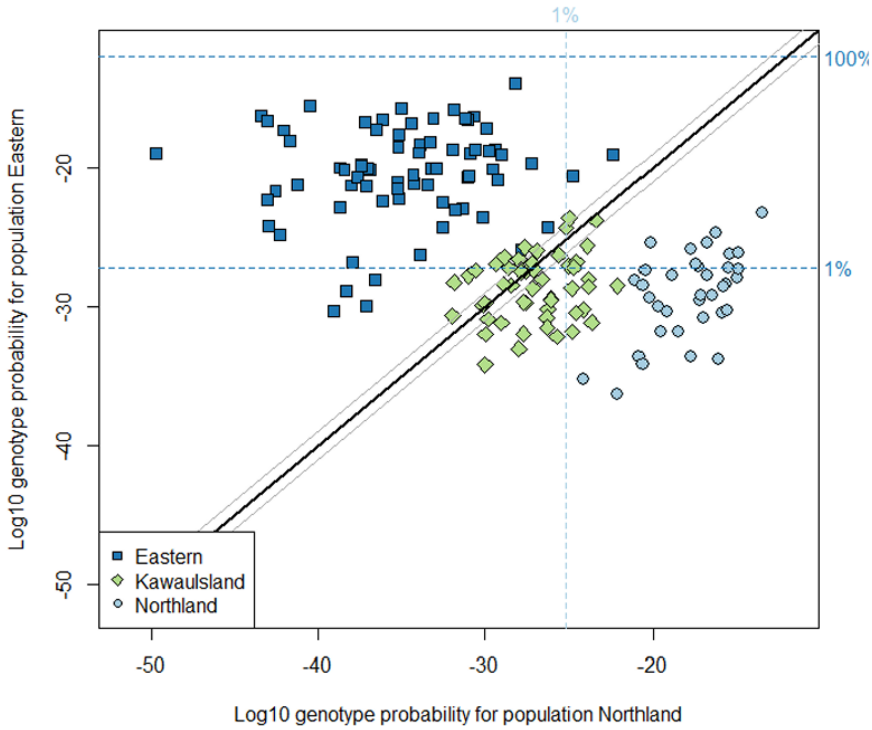

Figure 3. Pairwise assignment probabilities from GenePlots of the Kawau Island samples compared to Northland and Eastern population samples. Kawau Island samples that are to the right of the diagonal line and to the right of the 1% vertical dashed line group with Northland. Kawau Island samples on the left side of the diagonal line and between the horizontal 1% and 100% dashed lines group with Eastern. Samples within the dashed lines and between the bold and faint diagonal lines are the closest fitting samples, with samples directly on the bold line indicating equal fit to both populations.

Conclusions

The Kawau Island kiwi samples exhibited low genetic diversity compared to other NIB kiwi populations that had available data. Kawau Island kiwi pairs with high estimates of relatedness were reported, however there are expected to be many other related samples than reported herein. The low level of genetic diversity and limited number of alleles per marker in this population makes accurate relatedness and relationship estimation difficult, requiring a more in-depth analysis. There were alleles detected that appear unique to the Kawau Island population which were not detected in comparable population samples from the mainland (however please note these comparative samples vary in number and cannot completely represent these populations). The comparatively low genetic diversity along with the unique alleles may also suggest that the Kawau Island population has been isolated. Comparison of genotype data indicates that some individuals of the Kawau Island population could be assigned to at least the Northern and Eastern groups, perhaps indicating source populations of translocated birds.

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Additional Information

Remaining feathers will be returned as requested.

Remaining sample lysates will be disposed of in one month from this report date unless otherwise instructed.

Genotype data will be kept on file for future comparisons and analyses.

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Appendix: Consensus genotypes and sex test results for S1489 kiwi samples. Reported sex (*, 'N/A' when not indicated) and client identifiers submitted with samples included alongside EcoGene® identifiers used herein and throughout testing. Genotypes are where allele observed more than once, '0' indicates no alleles called per marker.

EcoGene ID	Client ID	Sex*	Z37B	KMS7R		KMS14B		KMS37		KMS1		Aptowe15		Aptowe8		Aptowe35		Aptowe39		Aptowe29		KMS18		Apt29		Apt59		Apt37		Apt35		Apt68		Aptowe1		KMS30		Aptowe3		Aptowe24		Aptowe34		Aptowe23		Aptowe28	
S1489_01	956000016242366	M	M	205	205	289	289	149	149	156	156	90	98	202	204	91	159	144	148	131	131	185	189	107	107	142	142	147	147	147	165	207	207	108	108	343	343	175	175	93	95	142	146	87	87	94	96
S1489_02	956000016266570	M	M	205	205	289	328	149	149	156	156	90	98	206	206	92	119	146	148	131	131	179	179	105	107	142	142	147	147	147	147	205	205	108	108	343	343	175	175	93	93	146	148	87	87	94	94
S1489_03	956000016279047	F	F	205	205	289	289	149	149	156	156	90	98	206	206	91	91	144	148	131	131	179	179	105	107	138	142	147	147	147	171	205	205	108	108	343	347	175	175	95	95	148	148	87	87	96	96
S1489_04	956000003732793	F	F	205	205	289	328	149	149	156	156	90	98	206	206	141	141	148	148	131	131	179	179	105	107	138	142	147	147	171	171	205	207	104	108	343	347	175	175	89	93	146	152	87	87	92	94
S1489_05	956000003610887	M	M	205	205	289	289	149	149	156	156	90	98	204	206	141	143	144	148	131	131	179	183	103	105	138	142	147	147	147	171	205	207	104	108	343	347	175	175	93	95	146	149	87	87	94	96
S1489_06	956000003736114	F	F	205	205	289	289	149	149	156	158	98	98	202	206	91	92	144	148	131	131	179	189	107	107	138	142	147	147	165	171	205	205	108	108	343	347	175	175	95	95	146	152	87	87	96	96
S1489_07	956000003733472	M	M	205	205	289	289	149	149	156	156	90	98	204	206	91	92	148	148	131	131	179	185	105	107	138	138	147	147	147	171	205	205	108	108	343	347	175	175	89	95	148	148	87	87	92	96
S1489_08	956000003614162	F	F	205	205	289	328	149	149	156	158	90	90	202	206	141	141	148	148	131	131	179	179	103	103	142	142	147	147	147	171	205	207	104	108	343	347	175	175	93	95	146	148	87	87	94	96
S1489_09	956000016284225	F	F	205	205	289	289	149	149	156	158	90	98	204	206	91	141	146	146	131	131	179	185	105	105	138	142	147	147	171	171	205	205	108	108	347	347	175	175	95	95	146	148	87	87	96	96
S1489_10	956000003726666	F	F	205	205	289	328	149	149	156	156	90	98	204	206	91	141	144	148	131	131	179	185	105	105	142	142	147	147	171	171	205	205	108	108	347	347	175	175	93	95	146	148	87	87	94	96
S1489_11	956000016279412	F	F	205	205	289	328	149	149	156	156	90	98	204	206	91	141	144	146	131	131	179	185	105	107	138	142	147	147	171	171	205	205	108	108	347	347	175	175	95	95	146	146	87	87	96	96
S1489_12	956000003736169	M	M	205	205	289	289	149	149	156	156	90	90	202	206	159	159	148	148	131	131	179	179	105	107	138	142	147	147	171	171	205	207	108	108	347	347	175	177	93	93	146	149	87	87	94	94
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S1489_16	956000015915720	M	M	205	205	0	0	149	149	156	156	98	98	202	202	91	92	146	148	131	131	179	183	105	107	138	142	147	147	147	171	205	205	104	104	343	347	175	175	93	95	148	149	87	87	94	96
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S1489_22	956000003734745	N/A	M	205	205	289	289	149	149	156	156	90	98	202	206	91	159	146	148	131	131	179	179	103	107	142	142	147	147	147	171	205	207	108	108	343	347	175	175	95	95	148	149	87	87	96	96
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S1489_44	978142000131116	M	M	205	205	289	289	149	149	156	156	90	90	204	206	91	159	144	146	131	131	185	189	105	105	138	138	147	147	165	171	205	205	108	108	343	347	175	175	95	95	146	146	87	87	96	96
S1489_45	978142000131965	M	M	205	205	289	289	149	149	156	156	98	98	204	206	91	143	148	148	131	131	179	189	103	107	142	142	147	147	165	171	205	207	104	108	343	347	175	175	95	95	146	152	87	87	96	96
S1489_46	978142000131879	M	M	205	205	289	328	149	149	156	158	90	98	206	206	92	119	146	148	131	131	179	183	103	107	142	142	147	147	147	147	205	207	104	104	343	343	175	175	93	95	148	152	87	87	94	96
S1489_47	978142000131809	F	F	205	205	289	289	149	149	156	156	90	98	206	206	92	141	148	148	131	131	185	189	103	103	142	142	147	147	147	165	205	205	108	108	343	343	175	177	93	93	146	148	87	87	94	94
S1489_48	978142000131746	F	F	205	205	289	289	149	149	156	156	90	98	206	206	91	92	146	148	131	131	179	185	105	107	142	142	147	147	147	171	205	205	108	108	343	347	175	175	93	95	146	148	87	87	94	96
S1489_49	978142000131191	M	M	205	205	289	289	149	149	156	156	98	98	202	204	91	141	144	144	131	131	179	185	103	107	142	142	147	147	171	171	205	205	108	108	347	347	175	175	95	95	142	146	87	87	96	96
S1489_50	978142000131061	F	F	205	205	289	289	149	149	156	158	90	98	202	206	141	159	148	148	131	131	179	179	103	107	142	142	147	147	147	171	205	207	104	108	343	347	175	175	93	95	142	148	87	87	94	96
S1489_51	978142000131302	M	M	205	205	289	289	149	149	156	156	90	90	202	204	141	141	148	148	131	131	185	189	103	103	142	142	147	147	165	171	205	205	108	108	343	347	175	175	93	95	142	146	87	87	94	96
S1489_52	Band# RA3494	F	F	205	205	289	328	149	149	156	156	92	96	192	192	92	129	144	148	131	133	179	189	105	105	138	138	147	151	153	153	205	207	104	104	343	343	175	175	97	97	148	148	87	87	94	96
S1489_53	Band# R65841	M	M	205	205	289	328	149	149	156	156	94	96	202	210	129	147	146	146	131	131	174	179	105	105	138	138	147	147	151	151	207	212	108	108	341	343	175	177	95	95	148	149	87	87	94	96

END OF RESULTS REPORT

Results apply to samples as received. This results report may not be reproduced except in full.

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