Mallard and Grey Duck Population Status

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1 SUMMARY

Grallards, the hybrid form of mallard and grey duck, remain the most popular gamebird species in the Auckland/Waikato region. This report updates population estimates from 2002–2025 using band-return data, harvest estimates from the Game Bird Harvest Survey, and improved estimates of band-reporting rates. The intent is to better understand long-term population trends, how confident we can be in these estimates, and what steps are needed to ensure robust monitoring for future management decisions.

1.1 CURRENT STATUS

The current population is considerably lower than in the early 2000s, with a decline occurring around 2009. Since that decline, the population appears to have stabilised at a reduced level, with year-to-year fluctuations of moderate magnitude. The 2025 estimate is among the lowest recorded in the last decade and similar to levels observed in 2019, 2021, and 2022. However, the drivers behind this recent drop require careful interpretation.

In particular, the 2025 estimate is strongly influenced by data from Aka Aka, a banding site in the Waikato River delta where birds have exhibited consistently high harvest rates. As Aka Aka contributed a large proportion of banded birds in 2025, and because harvest rates there were high (around 35%), the regional harvest-rate estimate increased noticeably. When this single site is removed from the calculation, the 2025 population estimate increases by approximately 115,000 birds. This does not necessarily imply that Aka Aka data is incorrect, rather, it highlights the sensitivity of the population estimates to where birds are banded and the importance of spatial representativeness in sampling.

1.2 INFLUENCES ON THE ESTIMATES

Long-term spatial analyses show that hunting effort and harvest intensity are concentrated in a handful of familiar hotspots such as the Waikato River delta, Whangamarino Wetland, the Waipa River, and the Hauraki Plains. Due to the significant time and financial constraints associated with carrying out banding programmes, banding is limited to five or six sites maximum per year. Therefore, there is a risk that a pooled estimate of harvest rate may not always be representative of the population.

Another factor that influences harvest-rate estimates is age structure. Juveniles consistently make up the majority of banded birds, largely due to how and when traps are set. Juveniles are generally more vulnerable to harvest than adults, and an overrepresentation of juveniles in the banding sample can inflate harvest-rate estimates and therefore underestimate population size. A sensitivity analysis showed that adjusting for this imbalance would have increased population estimates by more than 100,000 birds in around half of the years modelled. In the past few years, however, the influence of age bias appears minimal because adult and juvenile harvest rates have been similar.

Environmental variables such as seasonal rainfall, drought indices, and soil moisture did not explain annual changes in population estimates. Even during years with severe drought, no detectable population response was observed in this dataset. This does not rule out the influence of climate as environmental effects may operate over different spatial scales or in ways that are not captured by the indicators available. Population trends in the neighbouring

Eastern Fish & Game region closely match those seen here, suggesting that large-scale environmental forces are shared across regions.

1.3 Interpretation and Implications

The findings show a population that remains depressed relative to 20 years ago, but has not experienced an additional major decline. The 2025 decline appears to reflect a combination of high harvest rates at a single banding site and sampling imbalance rather than a sudden shift in region-wide population dynamics.

The elevated harvest rate observed at Aka Aka warrants continued attention. If similar harvest pressure occurs in other parts of the region, we may be underestimating the scale of potential overharvest. Conversely, if Aka Aka represents a uniquely productive local hotspot, its influence on regional harvest-rate estimates should be weighted accordingly.

1.4 Recommendations

Future work should focus on refining how banding data is used so it is representative of the local population. In particular, a weighting framework for harvest rate may improve how we account for uneven banding effort and annual changes in catch rate across the region. As with the 2025 Harvest Report, collaboration with other banding regions will likely be key to improving the broader understanding of the Auckland/Waikato population.

2 Introduction

Mallard (*Anas platyrhynchos*) and grey duck (*Anas superciliosa*) are well distributed throughout New Zealand and are the dominant gamebird species in the Auckland/Waikato region. Hybridisation between the two species now means that the population consists of a hybrid form, referred to here as grallard.

Despite having the potential to be a highly productive species (large clutch sizes, early sexual maturity), the Auckland/Waikato population has been trending downwards. Many factors may impact this, including, but not limited to, nest predation, duckling survival, habitat loss, harvest mortality, adult female survival, and environmental factors such as drought.

A recent study in the Waikato found that duckling survival is the most influential factor affecting population growth of mallards in New Zealand (Sheppard, 2017). Furthermore, the study found that a stable population is unlikely to be obtained by increasing breeding and non-breeding (i.e., harvest) survival of females alone (i.e., duckling survival would have to increase simultaneously), and that non-breeding survival rates would need to reach close to 0.9, which is not realistic for a game species (Sheppard, 2017).

To monitor the grallard population, the Auckland/Waikato region has run a banding program since 2002 and conducted harvest surveys since 1993. This report uses this data to estimate the Auckland/Waikato grallard population size from 2002 to 2025. In addition, investigate how changes in harvest rate, banding location, age composition, and environmental conditions affect these population estimates.

3 METHODS

3.1 ESTIMATING THE GRALLARD POPULATION

Grallard population size ($\widehat{N}$[1]) is calculated for each year using the Lincoln estimate (Lincoln, 1930), which states that if the proportion of the population harvested (harvest rate $\hat{h}$), and the total harvest $\widehat{H}$ are known, then the total population can be estimated by dividing $\widehat{H}$ by $\hat{h}$. This is more commonly written as:

$$\widehat{N} = \frac{b\widehat{H}\hat{\rho}}{r}$$

Where b is the number of newly banded birds, r is the number of newly banded birds shot in the preceding season (also called first-year returns), $\widehat{H}$ is the estimate of the total grallard harvest, and $\hat{\rho}$ is the probability of band reporting.

Estimates of total harvest are informed by data generated from the Game Bird Harvest Survey (GBHS), which runs over several survey periods that span the gamebird season. Within each period, a minimum of 120 full-season licence holders are phoned and questioned about how many ducks they harvested over that period. We estimate the average grallard harvest per person for each period. The sum of all periods represents the average harvest per person throughout the season. This can be multiplied by the number of licence holders to get an estimated total harvest for the year.

Values for b and r are known; however, because not all bands get reported, non-reporting each year is corrected by estimating the non-reporting rate ($\hat{\rho}$). Previously, data to estimate $\hat{\rho}$ was collected as part of the GBHS, and a three-year average was used due to estimates having high uncertainty and fluctuating considerably from year to year. In 2024 and 2025, a SMS survey was conducted with the aim of improving estimates (SMS Band Reporting Rate Pilot, 2024). The report found that the verified reporting rate in 2024 was approximately 52%. Given that this may be the least biased estimate of $\hat{\rho}$ this rate was extrapolated to all previous years estimates. There are naturally limitations to this. However, it is worth noting that:

1. No significant trend was observed over time based on the GBHS data.
2. Eastern's verified reporting rates[2] are also consistent over time, albeit a bit higher at around 58%.

Reporting rates for 2024 and 2025 (which had boosted reporting as a side effect of the SMS survey) were 56% and 58.8%, respectively.

It is also worth noting that $\widehat{H}$, $\hat{h}$ and $\hat{\rho}$ have their associated uncertainty, which needs to be included in the estimate of $\widehat{N}$. More details on this are found in the paper by Alisauskas et al. (2014).

The data was cleaned so that hand-reared birds were excluded from the analysis due to concerns that they were not representative (hand-reared birds are more likely to be harvested and more or less likely to be reported – depending on the site). Bands returned outside of the

[1] The "hat" notation signifies an estimated quantity.

[2] Which are also calculated in a way which means previous years data are used towards the current years estimate. Specifically a Bayesian approach with previous years estimates as priors.

hunting season were also excluded due to representing non-harvest mortality. Likewise, for birds banded outside of the region, but that appear in Auckland/Waikato banding database.

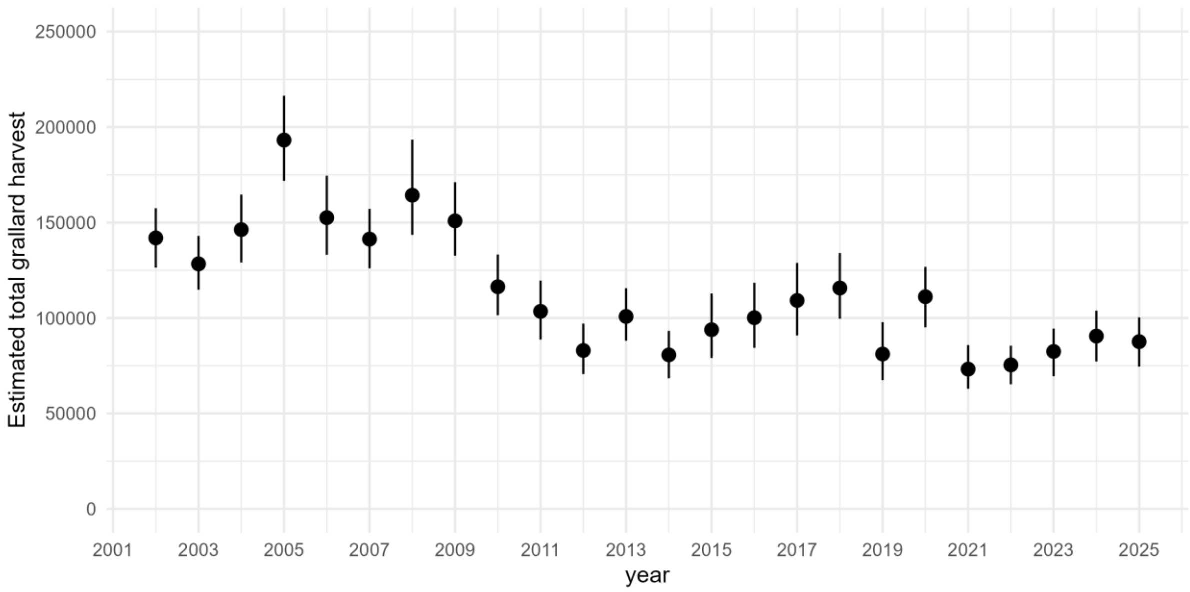

Figure 1: Auckland Waikato total grallard total estimated harvest $\widehat{H}$ from 2002 to 2025 (the years we have a banding programme) with 95% confidence intervals.

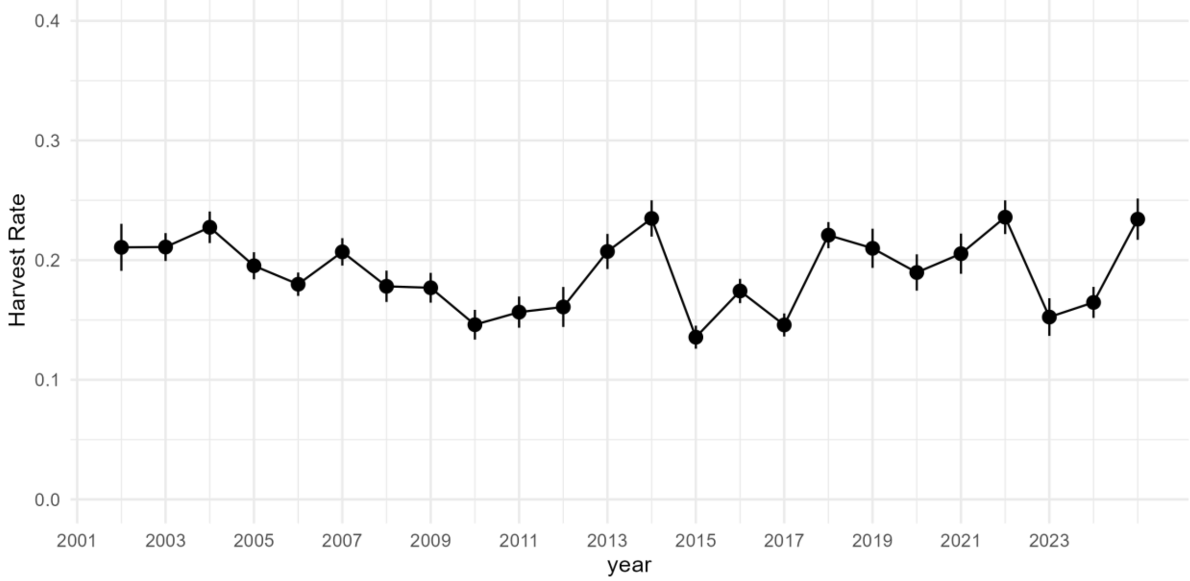

Figure 2: Estimates of grallard harvest rate $\hat{h}$ from 2002 to 2025. Harvest rates reflect the proportion of banded birds harvested within the first year and, assuming they are representative of the population, the proportion of the population that is harvested each year. Harvest Rates are corrected for verified non-response, which is estimated at 52% for years 2002-2023, 56% for 2024, and 58.8% for 2025, based on the 2024 and 2025 SMS survey results.

3.2 EXPLORING FACTORS THAT INFLUENCE GRALLARD POPULATION ESTIMATES

To better understand the factors that influence or potentially bias grallard population estimates, several complementary analyses were carried out. These analyses examined how harvest rate varies across demographic groups and banding sites, whether a potential overrepresentation of juveniles or early-season band recoveries could bias estimates, and how environmental or spatial factors might help explain variation in population size through time. Together, these investigations provide a framework for understanding the robustness of grallard population estimates and identifying where improvements in data collection or modelling could reduce uncertainty.

3.2.1 Harvest Rate

Because much of the year-to-year variation in population size is driven by changes in the estimate of harvest rate, harvest rate was calculated by age, sex and banding site area. There have been many different banding sites over the years, with some in very close proximity to each other. To examine trends over time in similar banding areas, sites within 15 km of each other were grouped together (Figure 19). The number of birds banded was quantified by banding site to examine how this may contribute to overall estimates of harvest rate. Additionally, the median distance travelled is estimated to indicate how far birds travel before being harvested.

Understanding differences in age, sex and banding site area are essential, as a pooled estimate of harvest rate may bias population estimates if it is made up of data that is not representative of the Auckland/Waikato population.

3.2.2 Estimating spatial patterns in harvest and hunter effort

As harvest rate is central to the Lincoln population estimator, spatial variation in hunting pressure can introduce bias if banding effort is uneven across the region. To evaluate this, spatial patterns in harvest and hunter effort across the Auckland–Waikato region were modelled using data from the Game Bird Harvest Survey (GBHS). This allowed the identification of areas that contribute disproportionately to overall harvest and assessment of whether the distribution of banding sites aligns with where most harvest occurs.

The region was divided into 25 km hexagons, with each respondent assigned geographic coordinates based on their most frequently reported hunting location during each survey period. As it is not known where non-hunting respondents would have hunted, participation at the hexagon level can not be estimated. Instead, daily participation rates were modelled at the regional level as a function of survey day and year, while spatial variation in harvest and hunting effort was modelled at the hexagon level.

A mixed-effects models is used to estimate these components. A binomial generalised linear mixed model (GLMM) was fitted to estimate the daily probability of hunting (participation), with season day as a fixed effect and year as a random effect. For respondents who hunted, a negative binomial GLMM estimated the expected number of grallard harvested per day, with random intercepts for both year and hexagon to account for spatial and temporal heterogeneity in harvest intensity. Predicted values from these models were combined to estimate the expected number of birds harvested per hunter per day.

Total days hunted and total grallard harvest per hexagon were then estimated by multiplying:

- the region-level daily participation probabilities,
- the number of licensed hunters in that year,
- the proportion of respondents assigned to each hexagon, and
- the hexagon-level mean.

Daily estimates were summed across the duration of the hunting season to generate annual totals for each hexagon. Results were averaged across all available years to describe spatial patterns in mean hunting effort (days hunted) and harvest intensity (grallard shot) across the Auckland–Waikato region.

3.2.3 Investigating an overrepresentation of juveniles and an unequal distribution of band returns

To assess the potential influence of age structure on harvest-rate and population estimates, a sensitivity analysis was conducted in which juvenile and adult harvest rates were given equal weighting. First, juvenile and adult harvest rates were estimated separately using standard band-recovery methods. The two estimates were then averaged, assuming a 1:1 juvenile-to-adult ratio in the population. The new harvest-rate estimate was used to recalculate grallard population size with the same Lincoln–Petersen framework used for the primary analysis. Finally, weighted population estimates were compared with the original (unweighted) estimates to evaluate the magnitude of any potential bias caused by disproportionate juvenile banding. This sensitivity test does not assume the 1:1 ratio is accurate; instead, it provides an upper-bound scenario to determine whether age-structure imbalance could meaningfully affect inference.

In addition, having observed that a high proportion of bands are returned early in the season relative to harvest[3] (i.e., around 51% of bands are returned on opening weekend, while opening weekend typically accounts for only about 40% of the total harvest), this patterns influence on the population size estimates was investigated. The Lincoln estimator assumes that all individuals have an equal probability of being harvested (equal catchability). However, because band recoveries appear to be concentrated on the opening weekend while total harvest continues to accumulate throughout the season (particularly in longer seasons), this assumption is violated. Consequently, there is a risk that the Lincoln estimates may be inflating population size in longer seasons, as harvest increases but few additional bands are recovered. To standardise this across years with long and short seasons, the Lincoln estimate using total harvest estimates and harvest rates from the first two weeks of the season was used. These estimates were scared to allow for trend comparisons over time between the two methods. A simple linear model was also fit to the scaled data to determine if the trends differed over time by method.

3.2.4 Environmental predictors

Efforts to date have looked at correlations between grallard population size, growth rate and harvest rate with seasonal rainfall, seasonal SPEI (drought index), and seasonal soil moisture deficit. Relevant seasons include the preceding winter, spring, and summer (e.g., using a 3-month average), as well as 3-, 6-, and 12-month averages for SPEI. Relationships post-2010 were also tested to examine more recent trends.

4 RESULTS

4.1 GRALLARD POPULATION ESTIMATES

The Auckland/Waikato grallard population, despite dropping from greater levels pre-2012, appears relatively stable across the last 10 years (albeit with a slight downward trend). The 2025

[3] Potentially due to the high proportion of juvenile birds in trap samples, which are naïve and therefore harvested at a higher rate compared to adult birds, especially earlier in the season.

estimate indicates a decline from the previous two years, putting it in line with lows also estimated in 2019, 2021 and 2022.

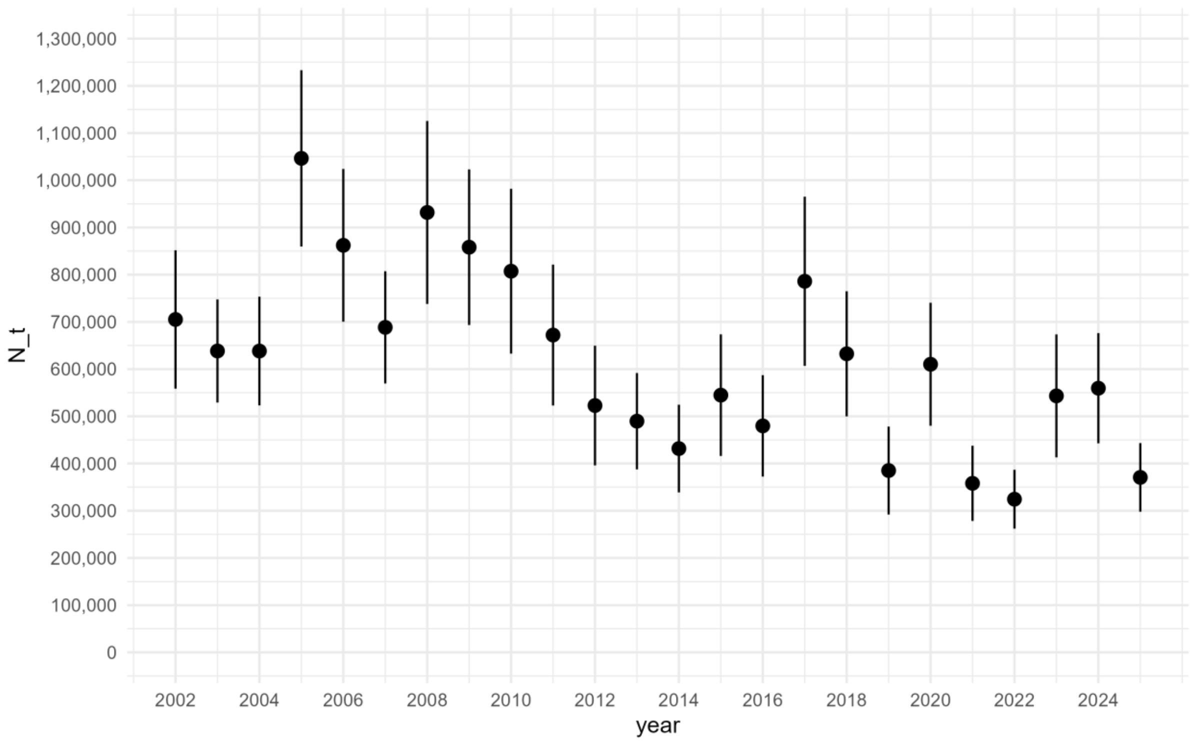

Figure 3: Auckland Waikato grallard population estimates $\widehat{N}$ from 2002 to 2025.

4.2 Factors influencing population size

4.2.1 Harvest rate

Harvest rates were broadly similar between males and females and followed comparable trends over time (Figures 4–5). Adults generally show higher harvest rates than juveniles, and these two groups show different patterns year to year. Since banding began, the proportion of juvenile birds caught in traps has remained consistently high (Figure 6), suggesting that the banding sample may overrepresent young birds.

Harvest rates also varied noticeably among banding site areas (clusters), both in their long-term averages and in how they changed over time. Helensville and Wellsford had the lowest average harvest rates (0.14 and 0.135 from 2002–2025), both showing a gradual decline. Pipiroa/Turua (Hauraki Plains, near the mouth of the Waihou), Opuatia, and Ohaupo had higher, more stable average rates (0.204, 0.183, and 0.188, respectively). Aka Aka shows the highest average harvest rate (0.252 across years with data), with several years exceeding 0.30, particularly in recent seasons. While harvest rates across most sites were relatively stable, Aka Aka appears to show an upward trend in recent years.

The distribution of birds captured (i.e., banding effort/success) has also shifted over time (Figure 8). The Opuatia/Whangape and Pipiroa/Turua sites, which once contributed most of the banded birds in the early 2000s, now represent a smaller proportion, while Aka Aka/Glenbrook, Helensville, and Ohaupo/Kerepehi have become more prominent. Wellsford, by contrast, has consistently had low catch rates throughout the period.

Median distance travelled by first-year birds also varied among banding sites but has been generally consistent through time (Figure 9). Most birds were recovered within 10–20 km of their banding sites, though the specific distances varied by area. For example, birds from Aka Aka, Ohaupo, and Wellsford were typically recovered closer to their respective banding sites (within 10 km), while those from Opuatia and Pipiroa were typically recovered farther away (10–20 km). Helensville was an exception, showing higher median distances and greater variability overall. This suggests that while movement patterns differ among sites, they have remained relatively stable over time.

Figure 4: Estimates of grallard harvest rate $\hat{h}$ from 2002 to 2024 by sex (M = male, F= female) and age (A= adult, J= juvenile). Harvest rates reflect the proportion of banded birds harvested within the first year and, assuming they are representative of the population, the proportion harvested each year. Harvest Rates are corrected for verified non-response, which is estimated at 52% for years 2002-2023, 56% for 2024, and 58.8% for 2025, based on the 2024 and 2025 SMS survey results.

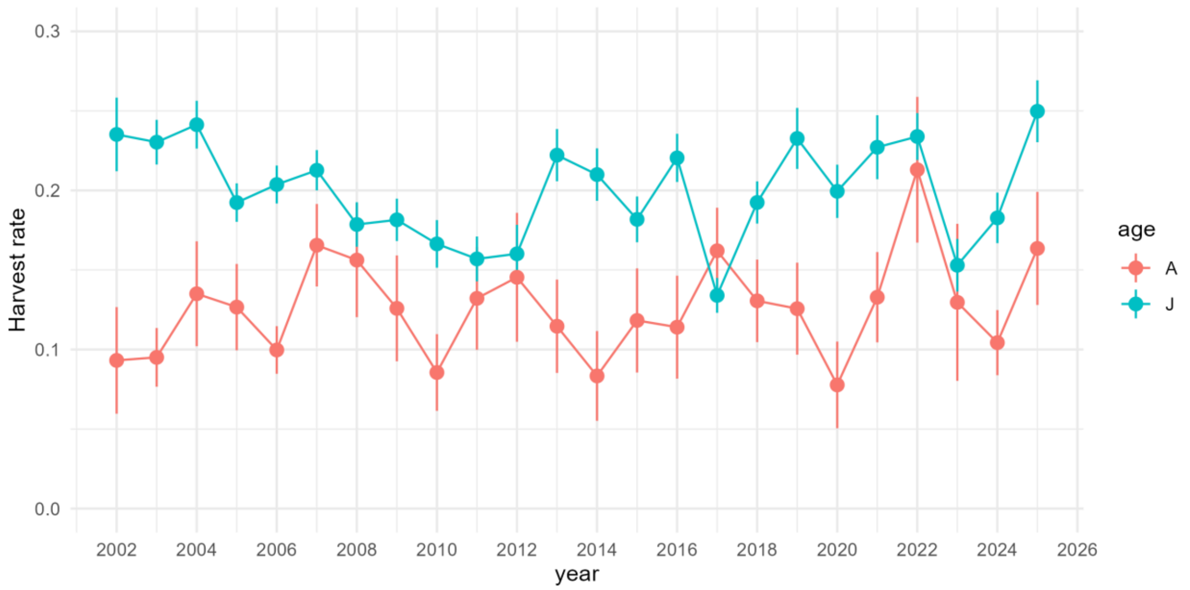

Figure 5: Estimates of grallard harvest rate $\hat{h}$ from 2002 to 2024 by age (A= adult, J= juvenile). Harvest rates reflect the proportion of banded birds harvested within the first year and, assuming they are representative of the population, the proportion harvested each year. Harvest Rates are corrected for verified non-response, which is estimated at 52% for years 2002-2023, 56% for 2024, and 58.8% for 2025, based on the 2024 and 2025 SMS survey results.

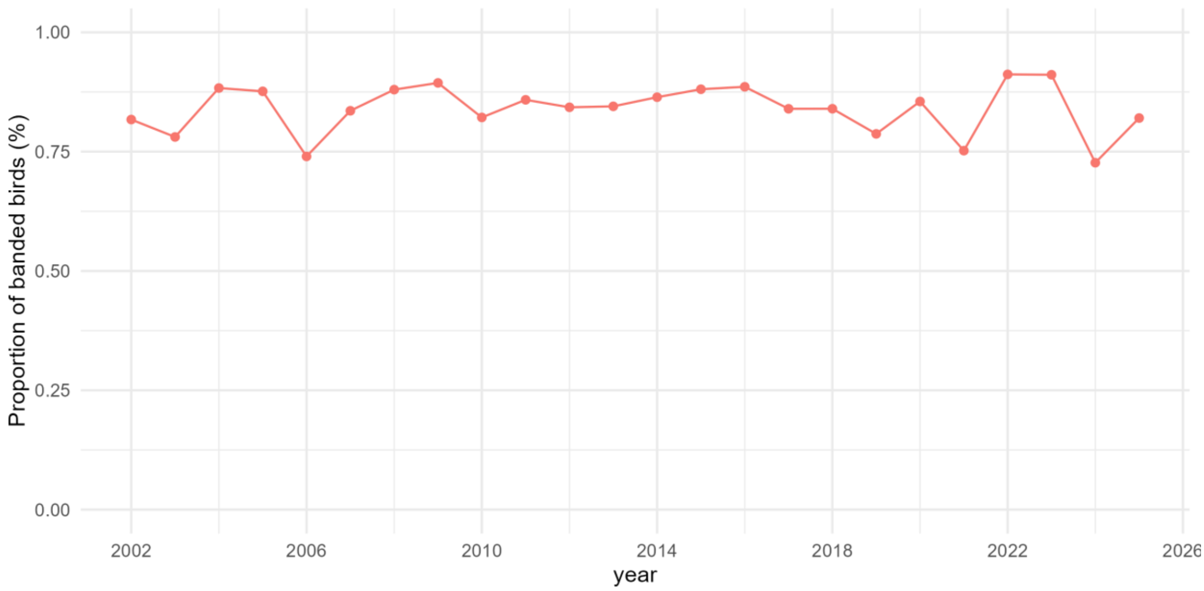

Figure 6: Proportion of banded birds that are juveniles from 2002 to 2025.

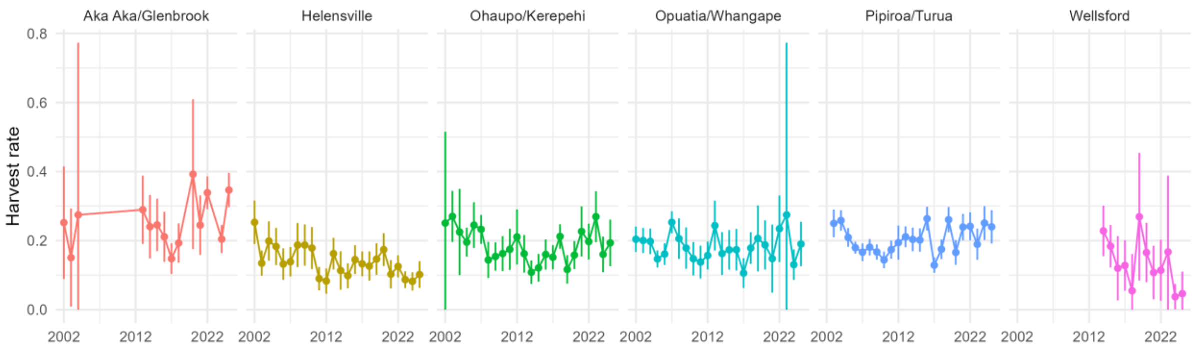

Figure 7: Estimates of grallard harvest rate $\hat{h}$ from 2002 to 2025 by banding site location (where banding sites within 15km of each other are grouped and those with less than five years of data are excluded). This illustrates how harvest rates differ over time based on where the birds are banded. Harvest Rates are corrected for verified non-response, which is estimated at 52% for years 2002-2023, 56% for 2024, and 58.8% for 2025, based on the 2024 and 2025 SMS survey results.

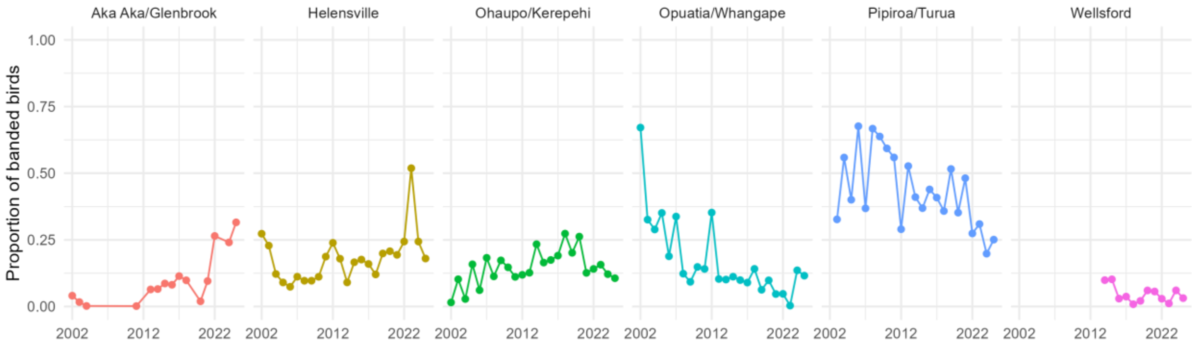

Figure 8: Number of birds banded from 2002 to 2025 by banding site location (where banding within 15km of each other are grouped and those with less than five years of data are excluded). This illustrates how banding effort (or success) has been distributed across the region over time.

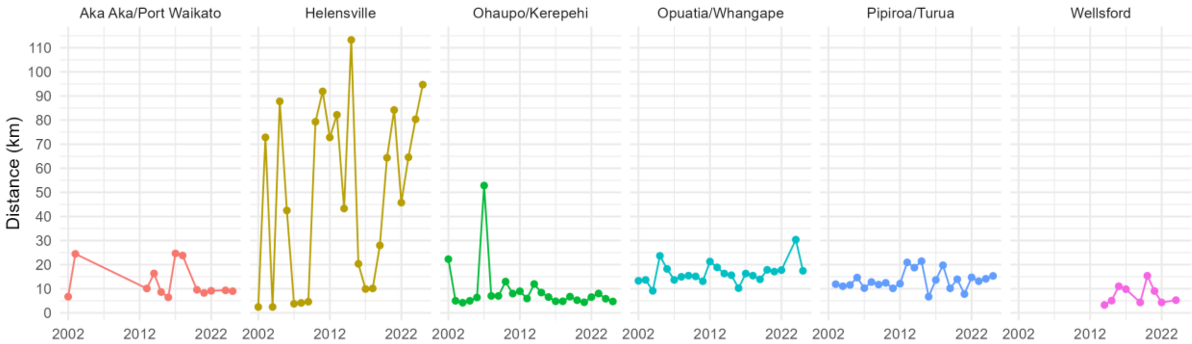

Figure 9: Median distance travelled by first year returns by banding site location (where banding sites within 15km of each other are grouped and those with less than five years of data are excluded). This illustrates that the distance birds typically travel before being harvested is often consistent over time but varies by banding site.

4.2.2 Spatial patterns in harvest and hunter effort

Spatial estimates of harvest and hunter effort for 2015 to 2025 combined show similar patterns (Figures 10 and 11). These are primarily driven by the distribution of where licence holders hunt throughout the region. The areas of the Waikato River, Whangamarino, Waipa River and Hauraki plains remain key areas of hunter activity and therefore harvest/effort.

In more recent years (2024 and 2025), harvest follows a similar pattern, with a significant proportion around the Waikato River Delta, Whangamarino, and Morrinsville/Te Aroha area (Figure 12).

Spatial estimates of grallard per hour from 2015 to 2025 are more uniform (Figure 13), with the Pipiroa area standing out with slightly higher estimates of grallard per hour. In comparison, 2025 shows a very consistent spread of success (grallard per hour) across the region (Figure 13).

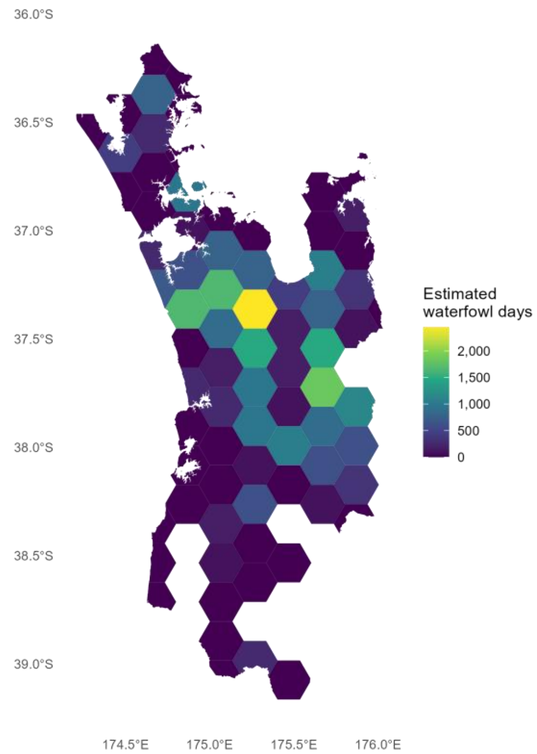

Figure 10: Spatial estimates of total days hunting waterfowl (average of years 2015 to 2025) in the Auckland Waikato region, highlighting areas of high hunter activity. Years are combined as individual years give weak spatial coverage.

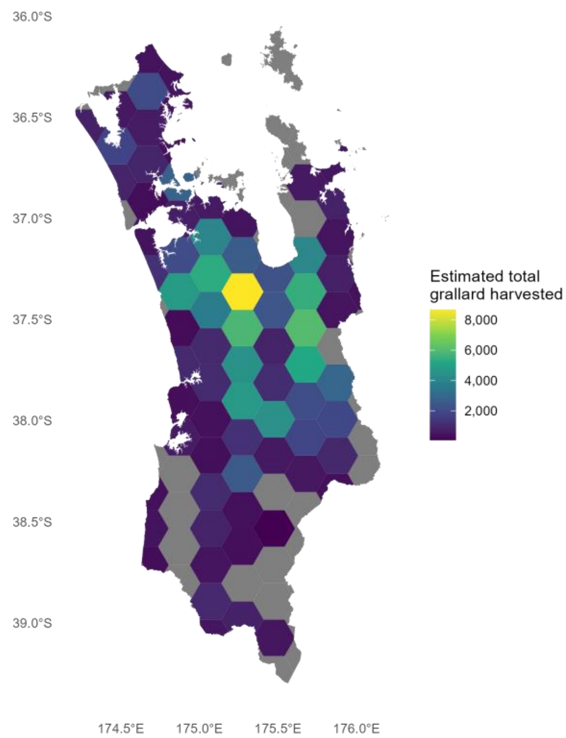

Figure 11: Spatial estimates of total grallard harvest (average of years 2015 to 2025) in the Auckland Waikato region, highlighting areas of high harvest across this period. Years are combined as individual years give weak spatial coverage.

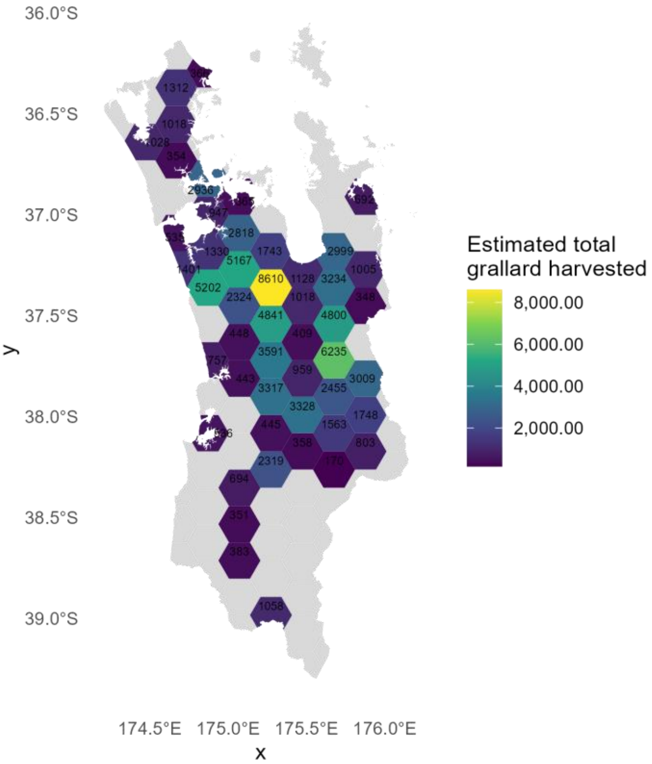

Figure 12: Spatial estimates of total grallard harvest (average of years 2024 to 2025) in the Auckland Waikato region, highlighting areas of high harvest across recent years.

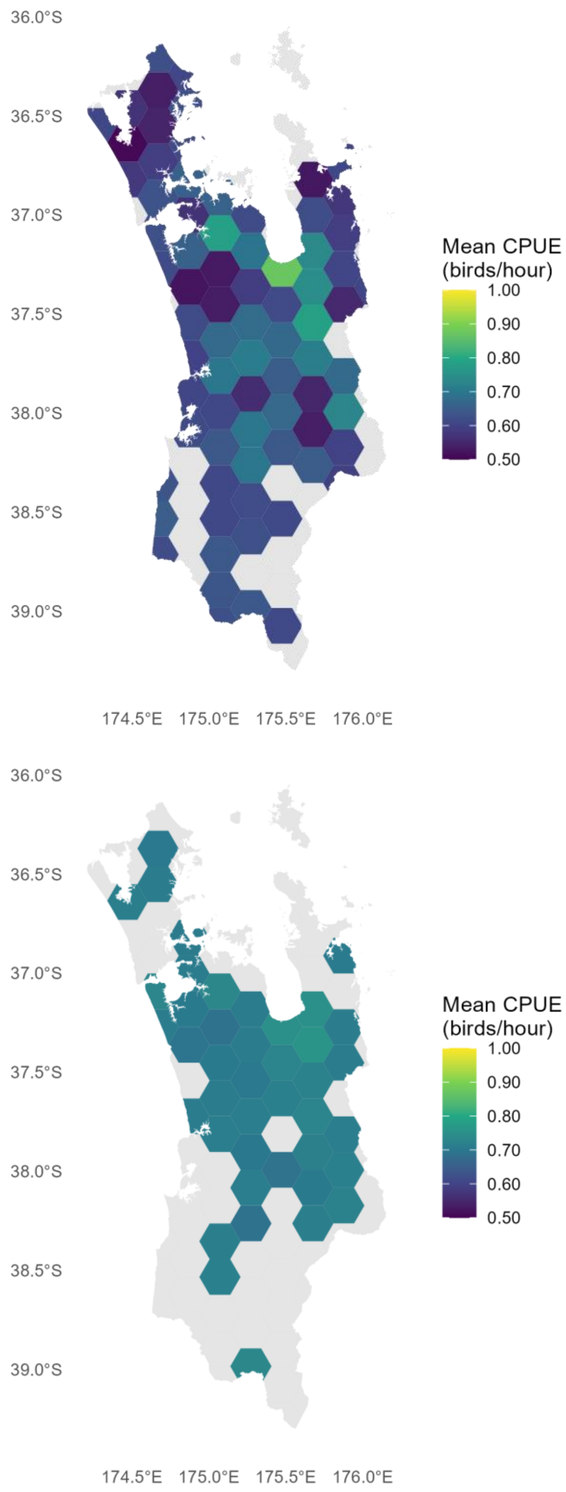

Figure 13: Spatial estimates of grallard per hour in the Auckland Waikato region 2015 to 2025 (top) and in just 2025 (bottom), highlighting areas of high hunting efficiency (which can be interpreted as a proxy for available birds/hunting success).

4.2.3 Imbalance in harvest and harvest rates

The proportion of bands returned in the first two weeks of the season has consistently been greater than the proportion of harvest from 2002 to 2025 (Figure 14). However, when the Lincoln estimate is applied to this data (i.e., using harvest and band returns from the first two weeks), the trend does not differ significantly compared to the regular estimates (Figure 15).

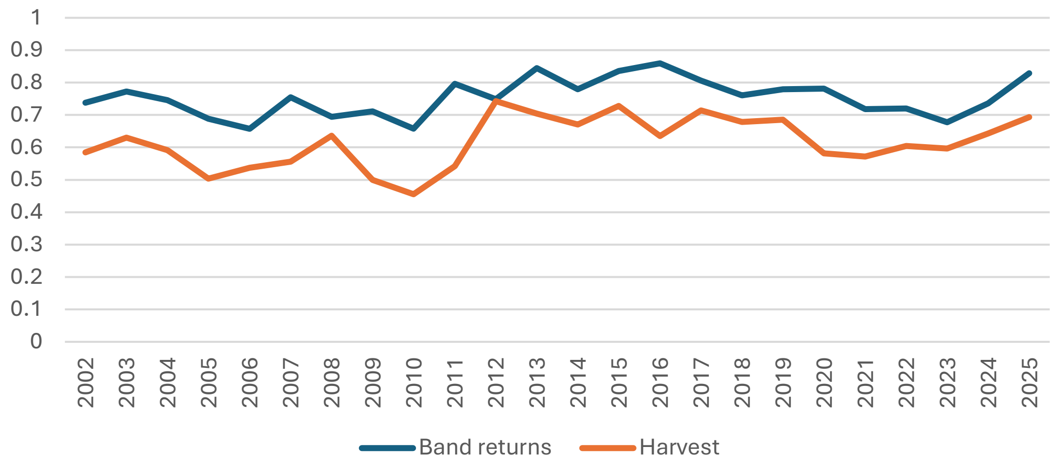

Figure 14: The proportion of harvest (orange) and band returns (blue) that occur within the first two weeks of the season from 2002 to 2025. The proportion of bands returned is consistently higher than harvest, indicating that the probability of harvesting a banded bird may not be equal throughout the season.

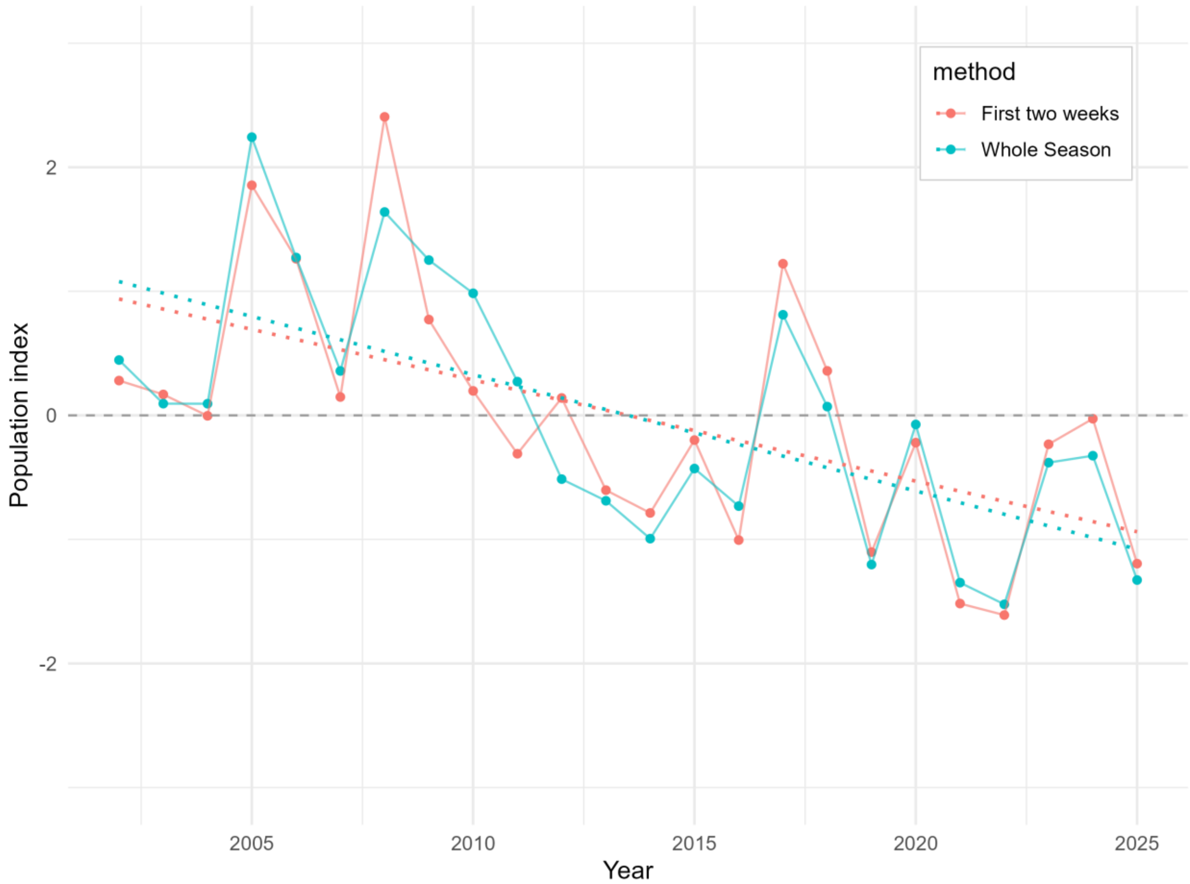

Figure 15: Estimates of the grallard population index (population estimate scaled for comparison in trends) based on harvest and band return data from all days in the season (blue) and from the first two weeks (red). Dotted lines are the linear trends.

4.2.4 Environmental predictors

As reported in the 2024/2025 harvest report, no statistically significant correlations were found between grallard population size, growth rate, and harvest rate with environmental variables. However, as this report shows that harvest rates vary by banding site area, it may be worthwhile to assess these factors while controlling for this variable.

5 DISCUSSION

5.1 2025 POPULATION ESTIMATES

Estimates of the 2025 grallard population size (Figure 3) indicate a decline from the previous two years, returning to levels last seen in 2019, 2021, and 2022, among the lowest in the past two decades. Given that total harvest has been relatively stable over the last five years (Figure 1), the downward shift in 2025 is primarily explained by a higher estimated harvest rate (Figure 2).

The 2025 harvest-rate increase appears to be driven by one banding site, Aka Aka, which is located near the Waikato River Delta. Birds banded at Aka Aka yield a site-specific harvest rate of 35.6% (assuming a 58.8% band-reporting rate), similar rate to the 34.5% observed there in 2022 (assuming a 52% reporting rate). The impact of this is significant as when including Aka Aka yields, the 2025 population estimate is 370,632 (95% CI: 310,922–430,342); however, when excluding all bands from the Aka Aka site the 2025 population estimate is 486,132 (95% CI: 393,661–578,602) - a difference of approximately 115,500 birds.

This raises questions around sample representativeness. If banding effort is not proportional to the true spatial distribution of the population (or to exposure to harvest pressure), overall harvest-rate estimates can be biased. Over-banding in lower-harvest areas pushes the overall harvest rate estimate down, while over-banding in higher-harvest areas pushes it up.

Figure 7 shows that banding sites around Aka Aka have experienced high harvest rates intermittently since 2020, but the proportion of birds banded[4] at this site has increased considerably since 2022 (Figure 8). This means that the influence of this higher harvest rate has only more recently had a greater impact on the overall estimate of harvest rate. Given that 50% of first-year birds are shot within 9km of the Aka Aka banding site, it is also reasonable to consider that this harvest rate may represent a highly localised area (Figures 9 and 17).

This is not to say that the harvest rates at Aka Aka are inaccurate or an outlier. The Waikato Delta is a popular hunting spot, with anecdotal evidence that this season was productive. Rather, the question is how much weight we should give to it. For example, if this area is representative of much of the Auckland/Waikato region (i.e., it is expected there are similarly high harvest rates in areas with less banding effort, such as the Whangamarino Wetland), there is considerable reason for concern. Conversely, if this represents a high-harvest hotspot, it may be incorrectly assumed that harvest is high across the entire Auckland/Waikato region, when it is only the case for a small, concentrated area (where a high proportion of birds happen to have

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[4] Banding effort has remained consistent, but catch rates have increased.

been banded in 2025). In other words, may have "over-banded" a localised high-harvest area relative to its share of the regional population, thereby biasing the regional harvest rate upward and, in turn, the Lincoln estimate of population size for 2025 downward.

The spatial estimates of harvest indicate that although total harvest and hunting activity around Aka Aka have been high in recent years (2024–2025), these values are broadly consistent with the long-term average from 2015 to 2025 (Figures 12 and 13). This suggests that, while Aka Aka remains a popular hunting area, recent harvest patterns have not changed markedly over time, nor is it an area of high hunter success, both in 2025 specifically or across the last 10 years (Figure 13).

This highlights the need to understand both the spatial variation in harvest rates and whether the current banding distribution reflects the true distribution of birds and exposure to harvesting. Hierarchical modelling approaches and spatial weighting schemes may offer practical pathways for quantifying site-level variability in harvest and ensuring that regional estimates are appropriately weighted. However, due to limited staff, banding efforts rely heavily on volunteers (and therefore are only able to be carried out on weekends), and efforts are constrained to a limited number of banding sites, and as such a conscious effort has been made to distribute these sites across the region, with sites in the Hauraki plains, Te Awamutu, Opuatia, Aka Aka and Wellsford.

Despite considerable year-to-year variability (i.e., from 2024 to 2025), there remains strong evidence of a large-scale population collapse circa 2009. This decline likely reflects a combination of factors, including more restrictive season regulations introduced in response to declining numbers and potential environmental pressures such as drought[5]. Because these factors occurred concurrently, it is not possible to separate the extent to which the post-2009 decline in harvest reflects a true reduction in population size versus the influence of regulatory change. Furthermore, without experimental controls—which are not feasible in this context—the influence of unmeasured factors such as changes in data collection, reporting rates, or hunter behaviour cannot be quantified.

Taken together, the 2025 estimates do not yet indicate a clear population shift, but rather emphasise the importance of accounting for spatial sampling imbalance before drawing strong conclusions about regional status or required management action.

5.2 Factors that influence the grallard population (or the estimate of it)

Based on the estimates of $\hat{N}$, it appears that the grallard population size has changed significantly over the last 22 years. Much of the year-to-year variation is driven by harvest rates.

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[5] "A drought event lasted from November 2007 to April 2008, during which the Waikato experienced its driest January in a century. A shortage of feed caused by the drought increased the price of silage to four times its normal rate. The cost of the drought was believed to be $1.5 billion to the Dairy sector alone. The economic effect of the drought was one of the factors that threw New Zealand's economy into recession by mid-2008. Waikato had dry springs in 2009 and 2010, which resulted in a double drought. The drought led to the owners of the Waikato River hydro scheme, Might River Power, announcing a 10 per cent drop in hydro production for the December quarter. Dairy farmers were estimated to have lost an average $100,000- $150,00 in income over the previous three years due to consecutive drought events." https://www.waikatoregion.govt.nz/services/regional-hazards-and-emergency-management/drought/

Firstly, it is shown that adult harvest rates do not vary significantly by sex. For juveniles, harvest rates for males are often higher than for females, but this is not consistent for all years. The most significant difference is between adults and juveniles, shown separately in Figure 5.

It is not particularly surprising that juvenile harvest rates are often higher than those of adults, as juveniles are more naïve and therefore easier to target, particularly on opening weekend. Interestingly, harvest rates for adults and juveniles do not seem to follow the same pattern (unlike sex). For example, in 2014, when juvenile harvest rates peaked, adult harvest rates were near their lowest (Figure 5).

Most birds banded in the Auckland/Waikato region are juveniles (Figure 6). While the true juvenile–adult ratio in the population is unknown, trapping locations and timing (late summer/early autumn) are believed to oversample juveniles. If this is the case, and juveniles are more vulnerable to harvest than adults, the harvest-rate estimates may be inflated, leading to an underestimation of population size.

To explore this, alternative population estimates were generated under a hypothetical scenario in which juveniles and adults occur in equal proportions (1:1). Under this assumption, juvenile and adult harvest rates contribute equally to the overall harvest rate estimate, rather than being dominated by juveniles (~90% of the band sample). This weighting frequently increased the population estimate relative to the unweighted approach. In 11 of 23 years, the population estimate increased by over 100,000 birds. However, in the most recent four years, the weighted and unweighted estimates are nearly identical due to similar juvenile and adult harvest rates.

This suggests that while age-structure biases may have influenced historical estimates, they are unlikely to explain recent changes in population size. However, properly correcting for this effect would require reliable estimates of juvenile-to-adult ratios in pre-season population information, which is not currently available.

The proportion of bands returned in the first two weeks of the season is disproportionately high compared to harvest. Figure 10 shows that across most years, there is a clear pattern of higher band-return proportions than harvest proportions, indicating that the probability of shooting a banded bird is higher at the start of the season. While there is likely a small effect whereby years with longer seasons have an estimated population size bias upwards (Figure 11), the effect is small enough that it is probably not worth worrying about.

5.2.1 Environmental factors

While some of the year-to-year variability in harvest rates may be explained by differences in age, sex and location (and how representative these are in the band sample), large drops in estimated population size may likely be caused by factors outside of control. The current hypothesis is that climatic conditions primarily drive annual changes in the grallard population. International literature has found strong links between droughts and mallard populations. However, there is no available evidence in the data that supports drought (i.e., rainfall, soil moisture deficit, etc.) as a predictor of grallard population size, despite there being some significant events in recent years. This may, in part, be due to variables such as rainfall being indirect and, therefore, blunt substitutes for the environmental factors that affect waterfowl. The lack of a relationship between population size and environmental conditions can be seen in comparing the population estimates with the drought index for Hamilton (Figure 17), by looking at the population size in a given year and the environmental conditions the preceding year. Given the scale of the Auckland/Waikato region, environmental conditions should likely be considered at more local scales, for which data are not always available.

Given the lack of a clear link between population size and environmental conditions, it is reassuring to observe similar trends in estimated population size with the Eastern region estimates, which are collected and analysed independently from the Auckland/Waikato Region. As with the Auckland/Waikato population estimates, Eastern Fish & Game observed a peak in numbers around 2005, a decline between 2010 and 2014, a large jump in 2015, and a relatively stable plateau at a reduced population from 2018 onwards (Figure 18). Similarities in population trends between neighbouring regions (with different harvest regulations) lend weight to the hypothesis that large-scale climatic patterns are the primary driver of changes to the grallard population. A combined analysis of banding data for North Island regions may improve the understanding of how environmental conditions impact the grallard population, and allow the development of an adaptive management system.

6 STAFF RECOMMENDATIONS AND NEXT STEPS

Overall, the grallard population in the Auckland/Waikato region remains low. However, recent fluctuations may reflect the sampling approach rather than a real decline. Regardless, there is little doubt that the Auckland/Waikato population is depressed relative to the levels observed in the early 2000s. In addition, the high harvest rate at Aka Aka an important factor that needs to be monitored.

Understanding factors that impact the estimate of population size are improving, however, further work is required to understand how harvest rates may be weighted to reflect hunter pressure. In addition, more deliberate work could be done to determine whether banding-trap samples allow better understanding of adult–juvenile ratios, or the effect that the disproportionate number of bands being returned early in the season has on population estimates. For both cases, it would likely be beneficial to collaborate with other regions that have banding programmes.

7 REFERENCES

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Lincoln, F. (1930). Calculating waterfowl abundance on the basis of banding returns. *U.S. Dept. of Agriculture*.

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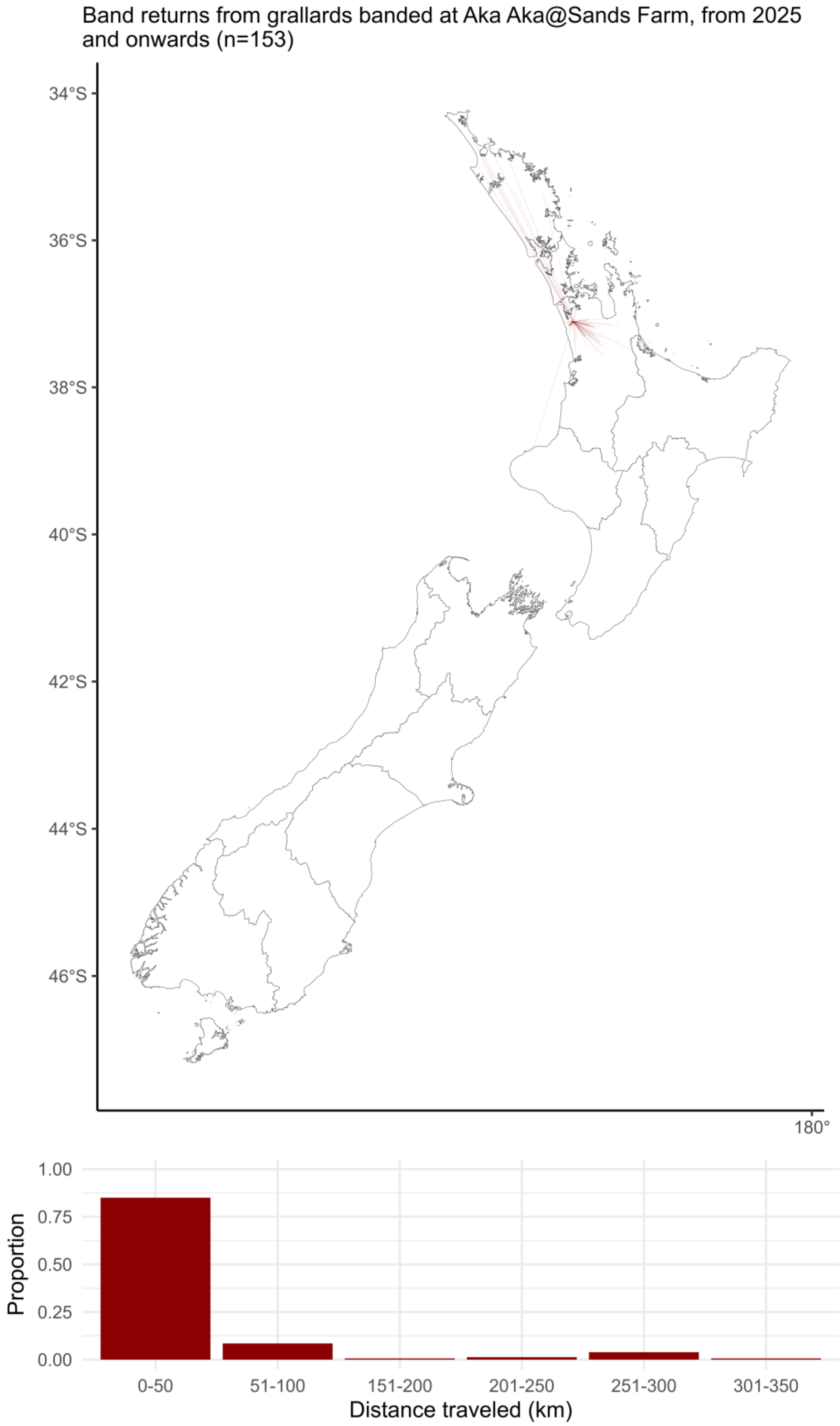
8 APPENDIX



Band returns from grallards banded at Aka Aka@Sands Farm, from 2025
and onwards (n=153)
34°S
36°S
38°S
40°S
42°S
44°S
46°S
180°
1.00
0.75
0.50
0.25
0.00
Proportion
0-50
51-100
151-200
201-250
251-300
301-350
Distance traveled (km)

Figure 16: Distances travelled by birds banded at the Aka Aka banding site in 2025. 50% of the birds were shot within 9.0 km of the banding site, while 90% were shot within 56.7km of the banding site.

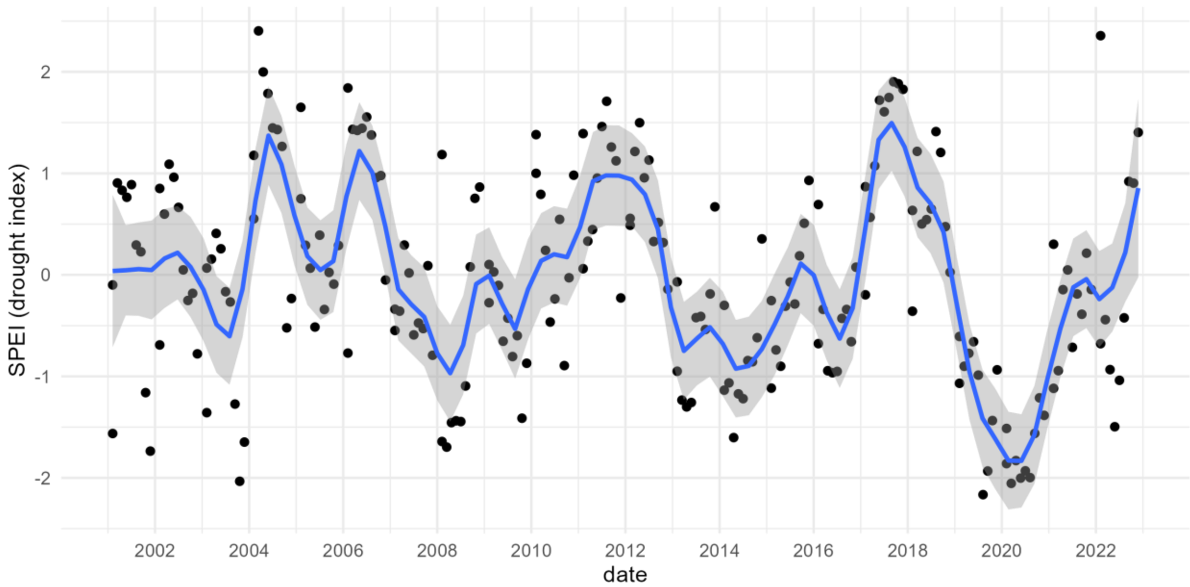


Figure 17: Standardised Precipitation Evapotranspiration Index (SPEI) for Hamilton 2002-2023. Here, values between -1 and 1 represent normal conditions, while values above 1 represent wet conditions and values below -1 represent dry conditions. Each point represents how wet or dry the previous 6 months were compared to the average. While 6-month averages may not best represent the temporal scale of environmental conditions that impact waterfowl, it is helpful to understand large-scale patterns over time.

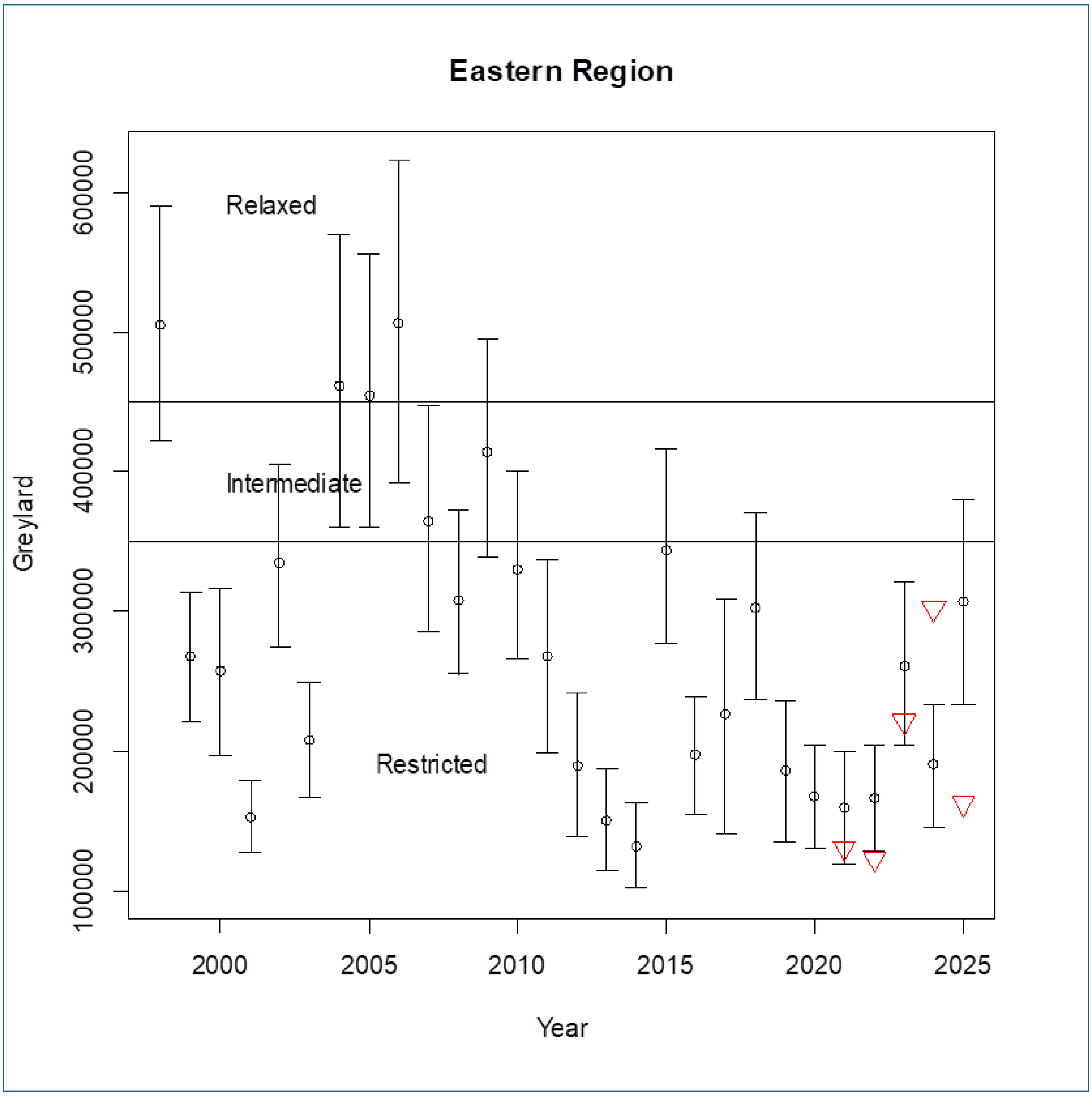


Figure 18: Grallard population estimates $\widehat{N}$ from 1998 to 2025 for the Eastern Fish & Game region.

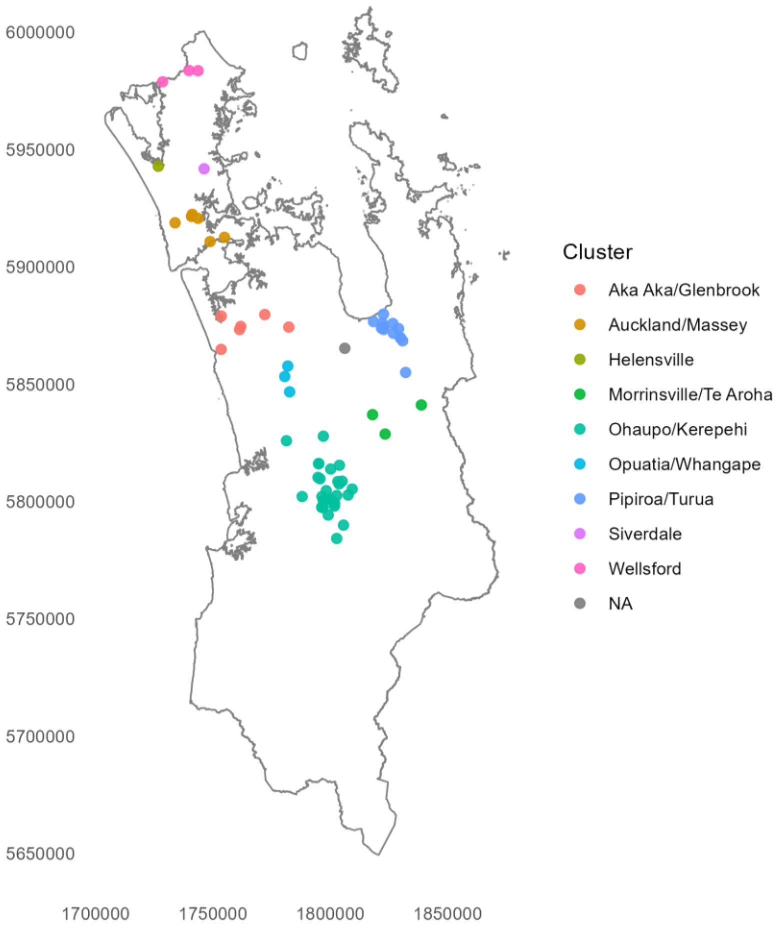


Figure 19: Auckland/Waikato banding sites coloured by their allocated banding cluster.