Trend Count Report for Paradise Shelduck, Black Swan, and Canada Geese

Beau Jarvis-Child 2025

1 SUMMARY

Auckland Waikato Fish & Game Council monitor paradise shelduck (*Tadorna variegata*), black swan (*Cygnus atratus*) and Canada geese (*Branta canadensis*) via aerial surveys of known moult sites at set times each year. Specifically, paradise shelduck are monitored in the King Country and north of Auckland via two separate surveys[1], while swan and geese are monitored in the Waikato lakes and harbours.

This report focuses primarily on estimating the population index and trends for paradise shelduck in the King Country and swan in the central Waikato lakes and harbours. North Auckland paradise shelduck and swan are also included (despite more limited data), as are Canada geese (despite no longer being managed by Fish & Game).

We employed hierarchical models (similar to route regression) to estimate an annual population index for each species, accounting for missing data and differences across locations. From these estimates, trends are calculated to determine the trajectory of the species in long-term and short-term scenarios.

Estimates of population index and associated trend indicate that:

- The King Country paradise shelduck population has decreased slightly in the last 10 years and seems to be following a downward trend of -1.35% annually since 1983.
- The central Waikato lakes and harbours' black swan population index appears relatively stable from 1986 to 2025.
- The central Waikato lakes and harbours Canada geese numbers have increased exponentially at a rate of 8.5% annually from 1986 to 2025.
- The North Auckland paradise shelduck population was reasonably stable from 2001 to 2016 and has increased significantly in the last decade.
- The North Auckland black swan population has declined slightly across the study period when counts of the Manukau harbour based on Auckland Airport and Bird NZ data are included. Trends appear to have remained stable over the last 10 years, but may have increased in recent years. When Manukau harbour counts are excluded, F&G counts indicate a drop in population, which, when coupled with Auckland Airport data, indicate that a number of swan have shifted from the Kaipara Harbour to the Manukau due to shifts in available food sources, resulting in concerns for aviation safety.

2 INTRODUCTION

The Auckland/Waikato Fish and Game Council uses aerial trend count surveys to estimate trends in populations of several game bird species, notably paradise shelduck and black swan. Although Canada geese are no longer managed by Fish & Game, we continue to monitor this species as these counts coincide with swan surveys.

These species congregate in areas for different annual phases, such as moulting or post-moult recovery, which results in a high proportion of birds being concentrated. Trend counts are timed to match the moult/moult recovery periods (around mid-January) and to coincide with a high tide event. Trend counts are not a full population count, even if, in some cases, a high proportion

[1] To date Northland have included the North Auckland paradise counts as part of their arial monitoring survey.

of the population is counted. It does, however, provide a "snapshot" of how the local population may be trending – either up or down. The underlying assumption is that the counts of the sample of sites (normally major sites) reflect what is happening to the local population as a whole.

3 METHODS

3.1 SURVEY METHOD

The counts are conducted from a fixed-wing aircraft (often a Cessna) at an altitude of approximately 150 metres (500 feet) with one or more observers. Observers count the number of birds at each site (or count one species each). Photographs are also taken to ground-truth the counts and verify observer accuracy[2].

3.2 FLIGHT SURVEYS

Three separate flights/surveys are conducted. Specifically:

1. The King Country, paradise shelduck flight.
2. The Central Waikato lakes and harbours, swan and Canada geese flight.
3. The North Auckland paradise shelduck and swan flight[3].

Maps of the sites are shown in the appendix.

3.3 DATA CLEANING

In some years, counts for specific sites are not made and are represented as NA values. It is unclear how the data was recorded in earlier years. For example, in the King Country Paradise counts, there are 25 sites in total; however, in 1983, only eight sites had non-zero counts. The concern here is that zero values are incorrectly assigned to sites instead of NA. We considered manipulating the data to change these counts to NA values until a non-zero count is observed. However, we instead opted to exclude data prior to 1988, as this is when many sites started reporting non-zero counts.

In some instances, sites with consecutive zero counts are excluded from the survey and are considered "lapsed". In the analysis, lapsed sites were removed because they contribute little data (i.e., a few counts over a 20-year period). In addition, all sites with sub-counts are combined to represent a single location.

Counts of paradise shelduck and swan north of Auckland are limited to a few sites and include significant missing data, especially in earlier years. To mitigate this, we included an additional eight sites from the Northland count data, which were identified as being close to the border and therefore constitute data from the same sub-regional population. Combining these counts is appropriate, in particular for swan, as large flights of birds are known to move between the Auckland Waikato region and the Northland region (Williamson, 1980, 1977).

For the North Auckland swan counts, data from Auckland Airports' swan surveys in Manukau Harbour were included. However, this monitoring began in 2014, meaning it does not provide

[2] To reduce observer error, observers also practice estimating aerial counts using resources such as https://www.fws.gov/waterfowlsurveys/forms/countingtest.jsp?menu=counting.test
[3] Historically conducted by the Northland Fish & Game region as part of their lower Northland survey.

information towards the long-term trend of this population. To account for this, we (1) estimated a population index for swan that excluded the Manukau Harbour, and (2) when including Manukau Harbour counts, we imputed counts for years prior to 2014 based on data trends from the Birds NZ National Waterbird Census. The Bird NZ counts indicated that fewer than 500 swan were observed on the Manukau Harbour between 2001 and 2014, and we imputed values of 500 for these counts.

For the Central Waikato lakes and harbours swan and goose counts, overlap in non-zero counts were investigated to determine if there were patterns in birds being recorded (i.e., sites being surveyed). However, there was no clear evidence of a significant change in sites monitored over time, so all zero values were retained (see Appendix Table 4). Swan data for 1984 and 1985 were excluded because the goose surveys began in 1986, and it is unclear whether all sites were surveyed in these years.

3.4 Modelling

If no data is missing, then the total count of birds can be used to make comparisons between years. Although this total count does not enable us to estimate the population size, we can assess its relative trend over time, provided we have reasonable coverage of ponds in the region. When missing data is present, statistical models can be used to account for this.

Historically, Fish & Game councils have used route regression to analyse trend count data. However, hierarchical models have been proposed over route regression due to their easy implementation, ability to address missing data, improved precision (smaller confidence intervals), and potential application of covariates Sauer (2011)[4].

We, therefore, model bird counts using a generalised linear mixed model (GLMM) via the *glmmTMB* package in R. Where Y_{ij} the bird count at site i in year j is modelled as a negative binomial distribution[5]:

$$Y_{ij} \sim \text{Negative Binomial}(\mu_{ij}, \theta)$$

Where μ_{ij} is the expected bird count and θ is the overdispersion parameter of the negative binomial distribution. The log expected bird count is then estimated as a linear function:

$$\log(\mu_{ij}) = \beta_0 + \beta_j Year_j + u_i$$

$$u_i \sim N(0, \sigma^2)$$

Where β_0 is the overall intercept, $\beta_j Year_j$ represents the fixed effect of year, and u_i represents the random effect of site.

This model includes year as a fixed effect to allow for explicit estimation of the annual variation in bird counts. Treating year as a categorical variable (i.e., factor) rather than a continuous variable ensures that the population index is estimated for each year, enabling the detection of nonlinear patterns over time. Year could be treated as a random effect following Sauer (2011); however, results were similar, and a marginal effect of year was deemed more intuitive to interpret.

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[4] Hierarchical models can be implemented under the Bayesian or frequentist framework. Here, the frequentist method is used.

[5] Due to it being count data, where the variance exceeds the mean.

A random intercept for site was incorporated to account for differences in bird abundance across different locations. By doing this, the model ensures that the estimated effect of year (the trend over time) is not biased by differences in the absolute number of birds at each site. Without this adjustment, a lake with naturally high bird counts could influence the year effects disproportionately, resulting in misleading conclusions about population trends. Essentially, the random effect for lake helps separate spatial variation (differences between lakes) from temporal variation (changes over years), improving the accuracy of the estimated trend. The inclusion of a random intercept for sites is particularly useful in handling missing data. Here, partial pooling helps estimate missing observations based on patterns observed in other years and other lakes.

For some models, the area (km^2) of the survey site was included in the model (either as a covariate or offset term) to account for the effect of pond size if it was deemed to improve model fit (measured via AIC).

Predictions are generated using the ggpredict() function in R. Predictions represent the expected bird count for each year, considering only the fixed effect of year while ignoring lake-specific variability. These predictions provide a generalised population-level estimate rather than site-specific estimates by excluding random effects.

3.5 Estimating trends

Sauer (2011) proposes that trends are estimated and expressed in two ways. Trends can be estimated as a consistent long-term population change by plotting a regression through the indices, or a more interval-specific estimate of the trend can be calculated based on the endpoints.

The first method looks at how the population has changed over time by drawing lines through the data. Here, the data is the annual estimates of the population index. These lines help show whether the population is generally increasing, decreasing, or staying stable.

- We draw one line that covers all the available years (shown in blue), which gives a big-picture view of the long-term trend.
- We also draw lines just for the last 10 years (red) and the last 5 years (orange). These help us determine whether recent trends differ from the long-term pattern.

To estimate the percentage change over time (per year), log-linear models were used to determine the rate of exponential change, which is then converted into a percentage. When plotting trends, log-linear estimates were back-transformed. The added benefit is that if there is an exponential pattern in population growth, it will be better captured by the model.

The second method estimates how much the population changes from one point in time to another. For example, if the estimated population index is 100 in 2010 and 200 in 2025, this method calculates the average annual growth rate over that period based on the counts of these two years. This helps show whether the population has increased or decreased over this time period. We apply this approach to the full-time span (from the first to the last data point), as well as to the most recent 10-year and 5-year periods. This provides the expected average percentage change in population index from one year to the next for each of those timeframes. Specifically, Sauer (2011) defines this as:

$$\text{Trend} = 100 \times \left(\left(\frac{marginal\ effect\ [\text{Max}\ t]}{marginal\ effect\ [\text{Min}\ t]} \right)^{\frac{1}{Max\ t - Min\ t}} - 1 \right)$$

4 RESULTS

4.1 KING COUNTRY PARADISE SHELDUCK POPULATION INDEX

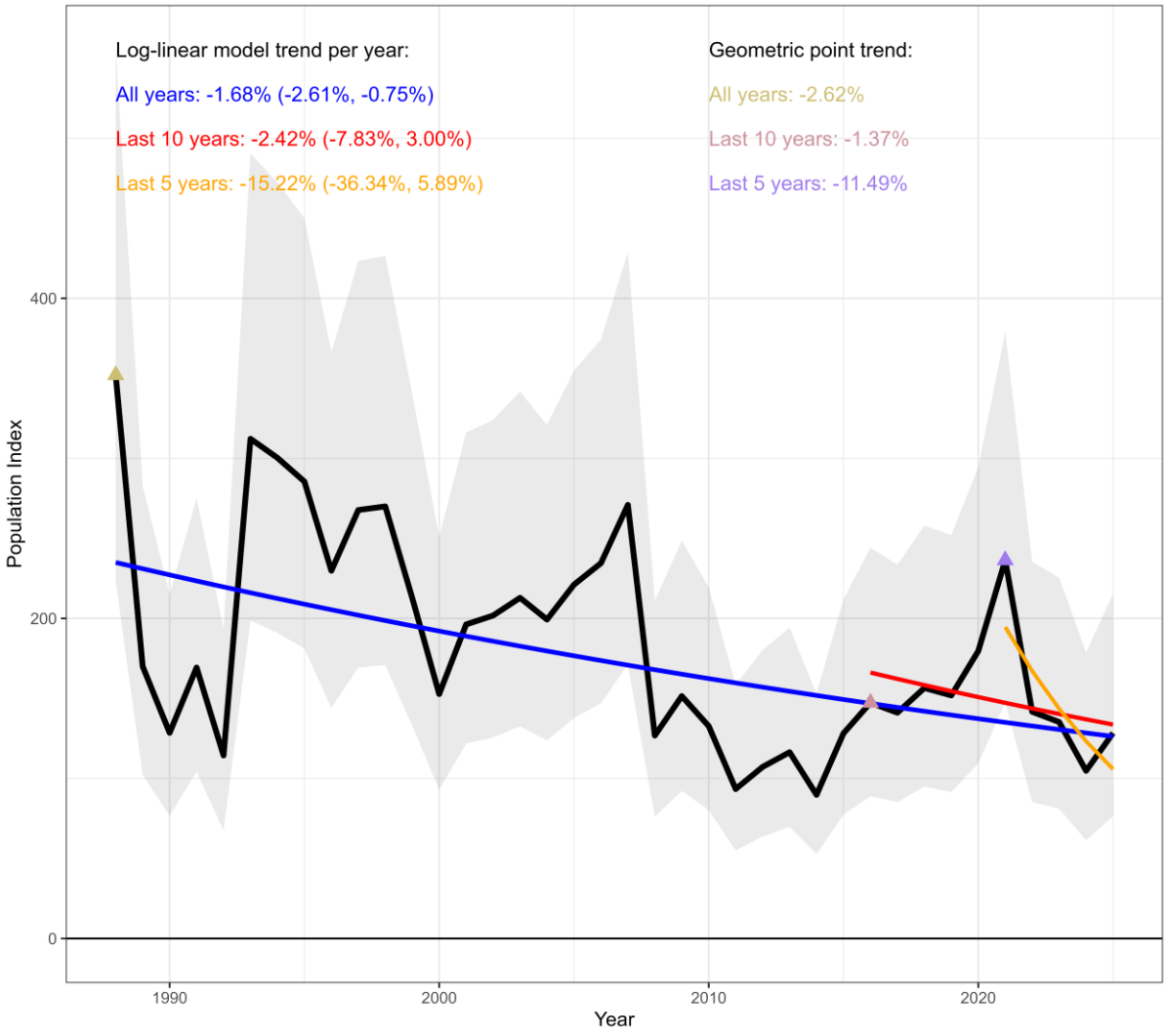

Figure 1: Estimated population index for paradise shelduck based on the King Country counts (black line) and associated confidence intervals (light grey). Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses. Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.

4.2 CENTRAL WAIKATO LAKES AND HARBOURS SWAN POPULATION INDEX

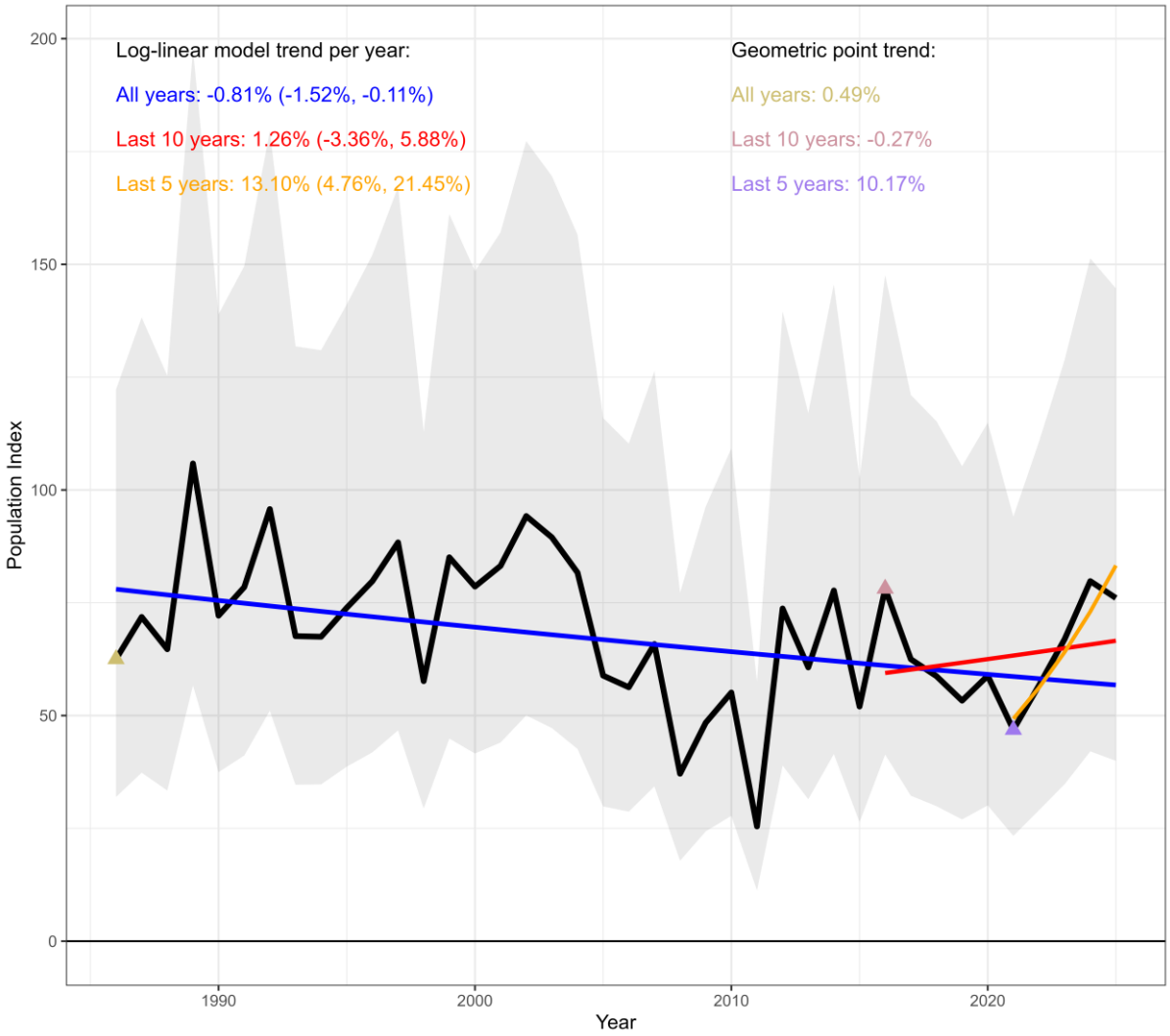

Figure 2: Estimated population index for black swan based on the Central Waikato lakes and harbours counts (black line) and associated confidence intervals (light grey). Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.

4.3 CENTRAL WAIKATO LAKES AND HARBOURS CANADA GEESE POPULATION INDEX

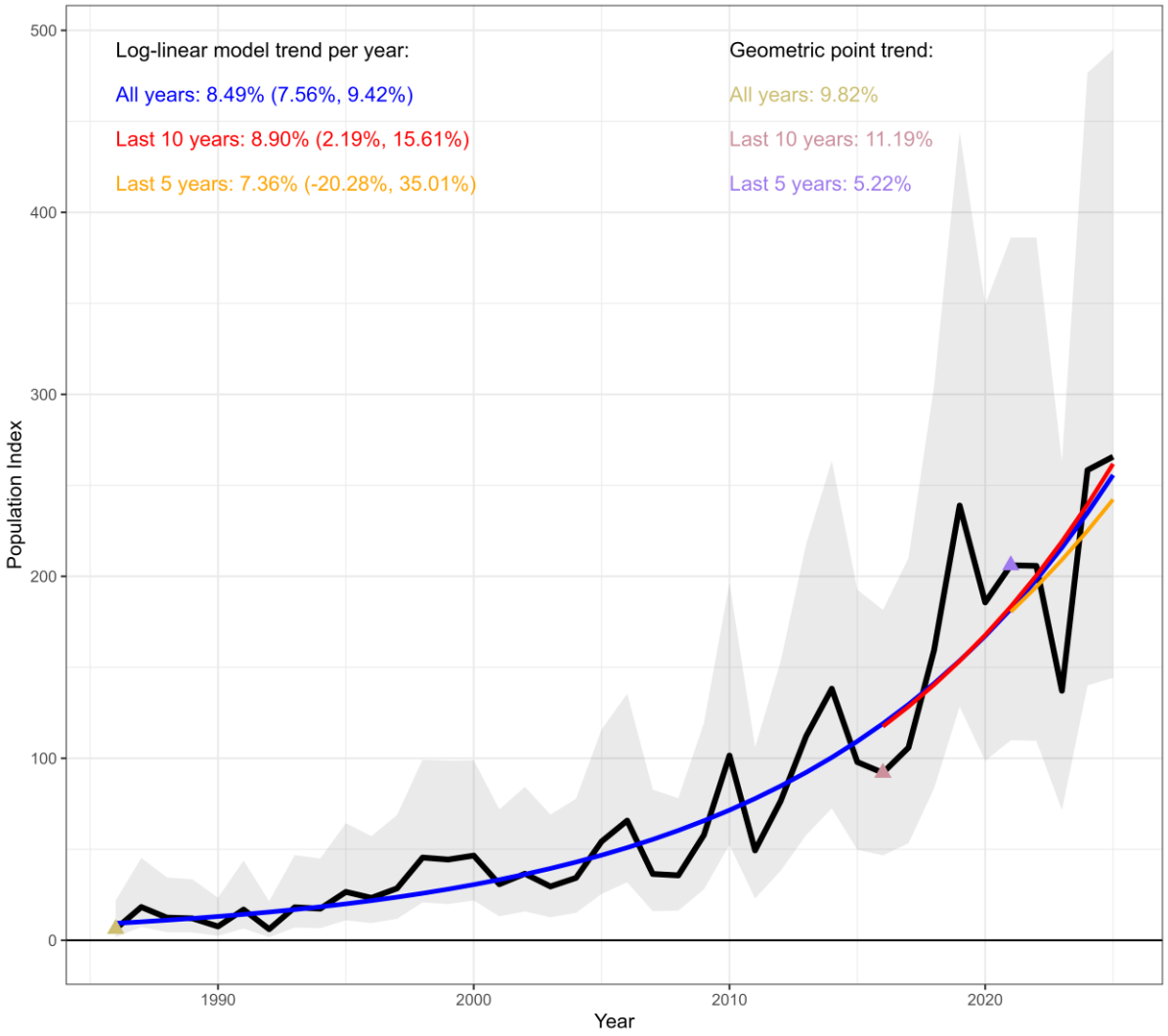

Figure 3: Estimated population index for Canada geese based on the Central Waikato lakes and harbours counts (black line) and associated confidence intervals (light grey). Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses. Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.

4.4 NORTH AUCKLAND PARADISE SHELDUCK POPULATION INDEX

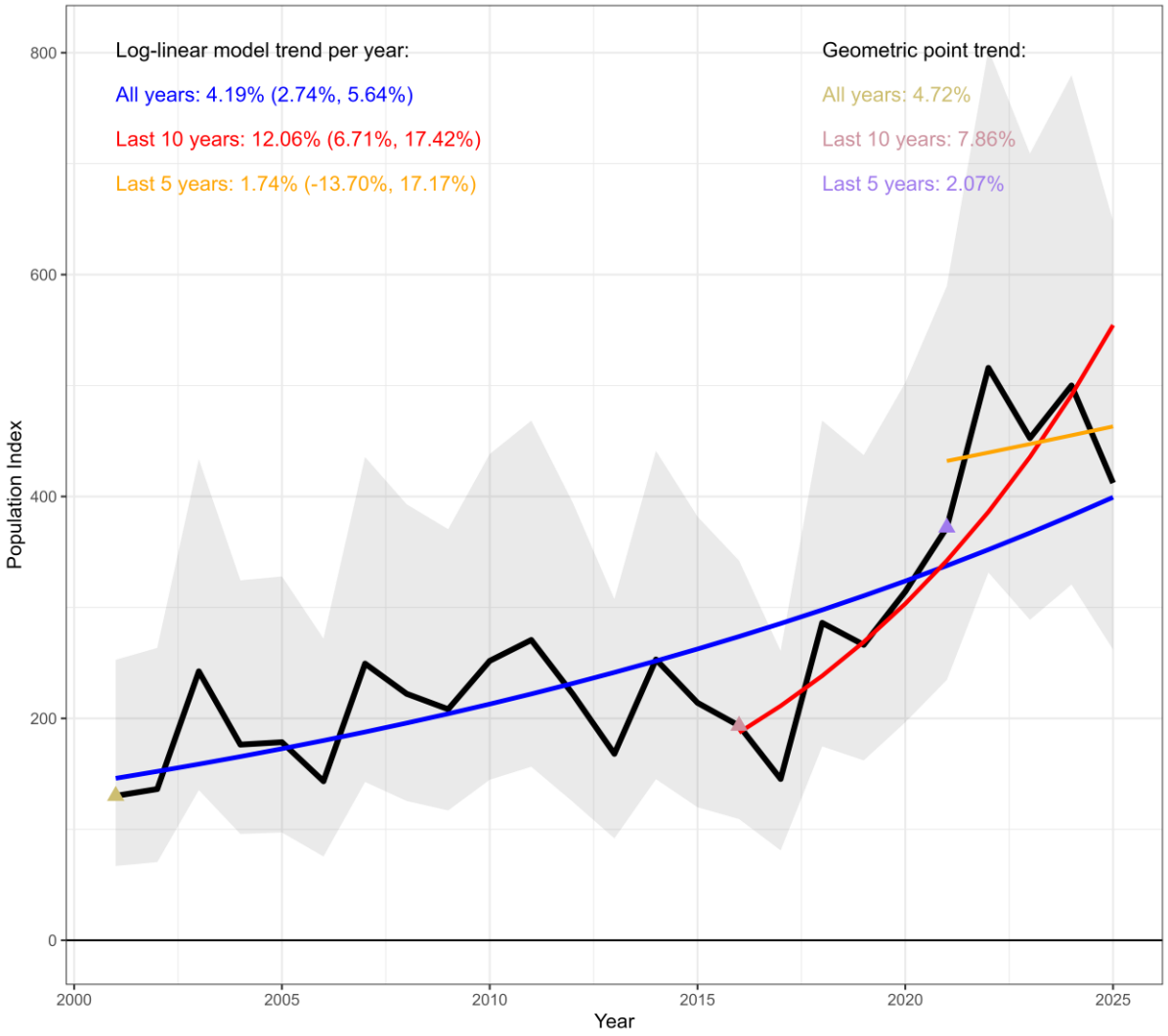

Figure 4: Estimated population index for paradise shelduck based on the north Auckland counts (and nearby Northland sites) (black line) and associated confidence intervals (light grey). Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses. Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.

4.5 NORTH AUCKLAND BLACK SWAN POPULATION INDEX

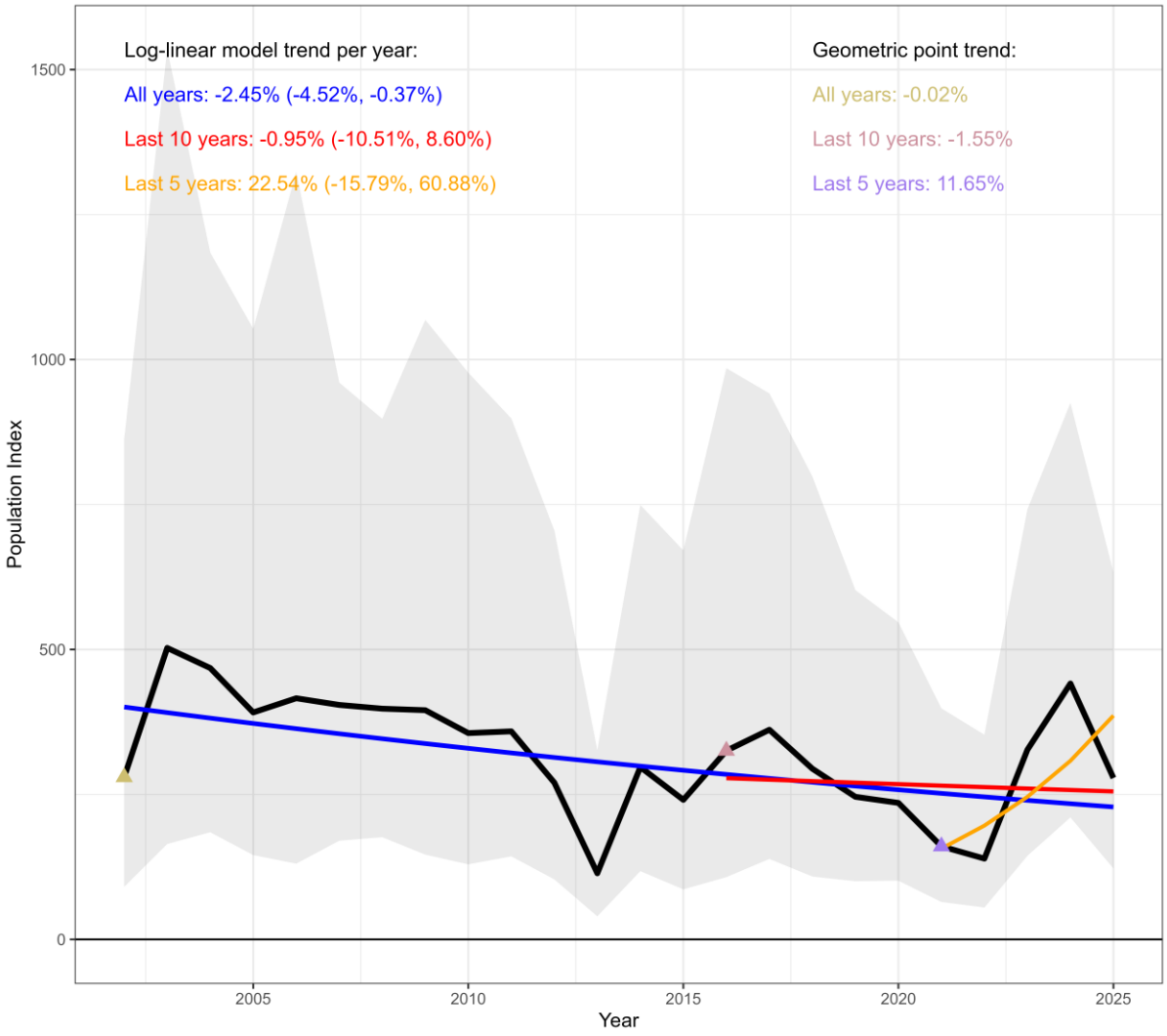

Figure 5: Estimated population index for black swan based on the north Auckland counts (and nearby Northland sites) and Auckland Airport counts of Manukau Harbour (black line) and associated confidence intervals (light grey). Here, Auckland Airport counts of the Manukau harbour prior to 2014 are imputed with values of 500 based on data from the Birds NZ National Waterbird Census. Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses. Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.

5 Discussion

Data for the King County paradise shelduck survey have good spatial coverage and complete records dating back to the early 1990s. Model estimates and associated trends indicate that the paradise population in the King Country is decreasing from 1988 to 2025 with a long-term linear decline of -1.68% (95% CI from -2.61% to -0.75%) per year. Over the last 10 years, the population has exhibited a similar decreasing trend; however, in more recent years, the decline appears to have accelerated (-15.22%, with a 95% CI that overlaps zero), albeit from a relatively high estimate circa 2021.

The Central Waikato lakes and harbours' black swan surveys also benefit from more complete data and longer temporal coverage. Estimates and associated trends indicate that the black swan population at these sites has declined slightly from 1986 to 2025 at a rate of -0.81% (95% CI from -1.52% to -0.11%) per year. In recent years, the population appears to have increased. However, this increase coincides with population estimates similar to those of the period between 1990 and 2000. In other words, the population may have recently returned to similar levels as observed in the 90s, after dropping around 2010.

Canada geese estimates based on data from the survey of Central Waikato lakes and harbours indicate that the population follows a pattern of exponential growth. From 1986 to 2025, the population increased at a rate of 8.49% (95% CI from 7.56% to 9.42%) per year. Trends based on estimates of the prior 10 and 5 years show no evidence that this is slowing down.

The North Auckland paradise shelduck survey includes counts from 11 sites in the Auckland/Waikato region[6] and eight sites in the Northland region close to the region's border. Including the Northland sites allowed us to extend the temporal coverage of our estimates and provided more data in the earlier years where estimates had high uncertainty. Model estimates and associated trends indicate that the paradise population north of Auckland is increasing over the period from 2001 to 2025, with a long-term linear trend increase of 4.19% (95% CI from 2.74% to 5.64%) per year. Over the last 10 years, the population has experienced a dramatic increase of 12.06% (95% CI: 6.71% to 17.42%) per year. However, in more recent years, the population growth appears to have stabilised (1.74% population increase, with 95% CI overlapping zero).

The North Auckland swan survey includes counts from 11 sites in the Auckland/Waikato region and eight sites in the Northland region, near the regional border. Counts of the Manukau Harbour based on Auckland Airport monitoring post 2014 are also included, with counts prior to 2014 imputed at 500 swans based on data from Bird NZ National Waterbird Census[7]. If counts before 2014 are not imputed, estimates suggest a significant population decline, which does not align with expert opinion. When comparing estimates of swan excluding the Manukau Harbour (Figure 11) with Manukau Harbour counts (from Auckland Airport and Birds NZ), it becomes apparent that one decreases while the other increases. This pattern would suggest a redistribution of birds, i.e., from Kaipara to Manukau. Overall, model estimates and associated trends indicate that the black swan population around and north of Auckland may be decreasing across the period from 2001 to 2025, with a long-term linear trend of -2.45% (95%

[6] Estimates and associated trends of paradise north of Auckland based on just the Auckland Waikato F&G sites are presented in the appendix.

[7] Estimates and associated trends of swan north of Auckland, excluding the Manukau Harbour, are presented in the appendix.

CI from -4.52% to -0.37%) per year. Over the last 10 years, it appears stable, with a slight increase of 0.41% (95% CI overlap zero: -9.02% to 9.84%) per year. However, in more recent years, the population growth appears to be significantly greater, with an estimated annual growth rate of 23.90% (with a 95% CI that overlaps zero). It is worth reiterating, however, that these estimates are based on data from multiple sources (with varying survey methodologies) as well as imputations. This means that while they may provide a more accurate representation of the broader population, they are not without their limitations.

Future efforts in monitoring bird numbers in these areas should focus on the current sites used in this analysis. While including new sites is always advantageous, it is more important to have long-term data on specific sites. Furthermore, excluding sites because they are no longer holding birds does not align with a structured monitoring programme. Estimates of black swan North of Auckland would also benefit from non-imputed counts in the Manukau Harbour before 2014.

5.1 Management Implications

- King Country Paradise: retain current bag limits and season durations. Decreasing counts may result in fewer special seasons if this decreasing trend continues.
- Swan: Retain current bag limits and season durations.
- North Auckland Paradise: an increasing trend may allow for more liberal harvest regulations for the gamebird season and special season North of the Auckland Harbour Bridge. For example, bag limits could be increased to match Northland's limits of 25. This will be considered in the upcoming regulation review.

6 References

Sauer, J. R., & Link, W. A. (2011). Analysis of the North American Breeding Bird Survey using hierarchical models. *The Auk, 128*(1), 87–98. https://doi.org/10.1525/auk.2010.09220

Williams, M. (1977). *Locations of recoveries of Black Swans, Cygnus atratus Latham, banded at Lake Whangape and Lake Ellesmere, New Zealand.* Wildlife Service, Department of Internal Affairs.

Williams, M. (1980). *The demography of New Zealand's Cygnus atratus population.*

7 Appendix

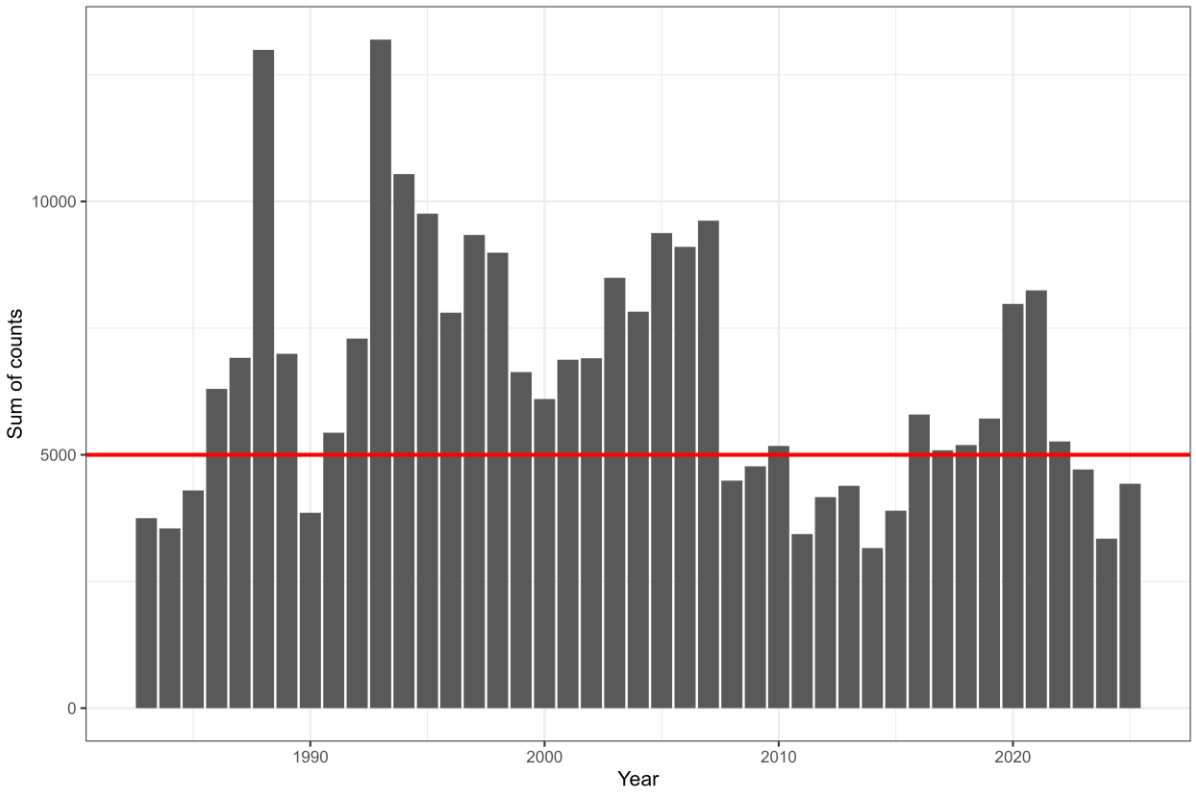

Figure 6: Sum of counts of King Country paradise shelduck. Because most sites are counted each year the total across all sites has historically been used to estimate relative change in the population over time. Further, a total of 5,000 birds across the sites is used as a threshold for hosting a "special season" in summer (red line).

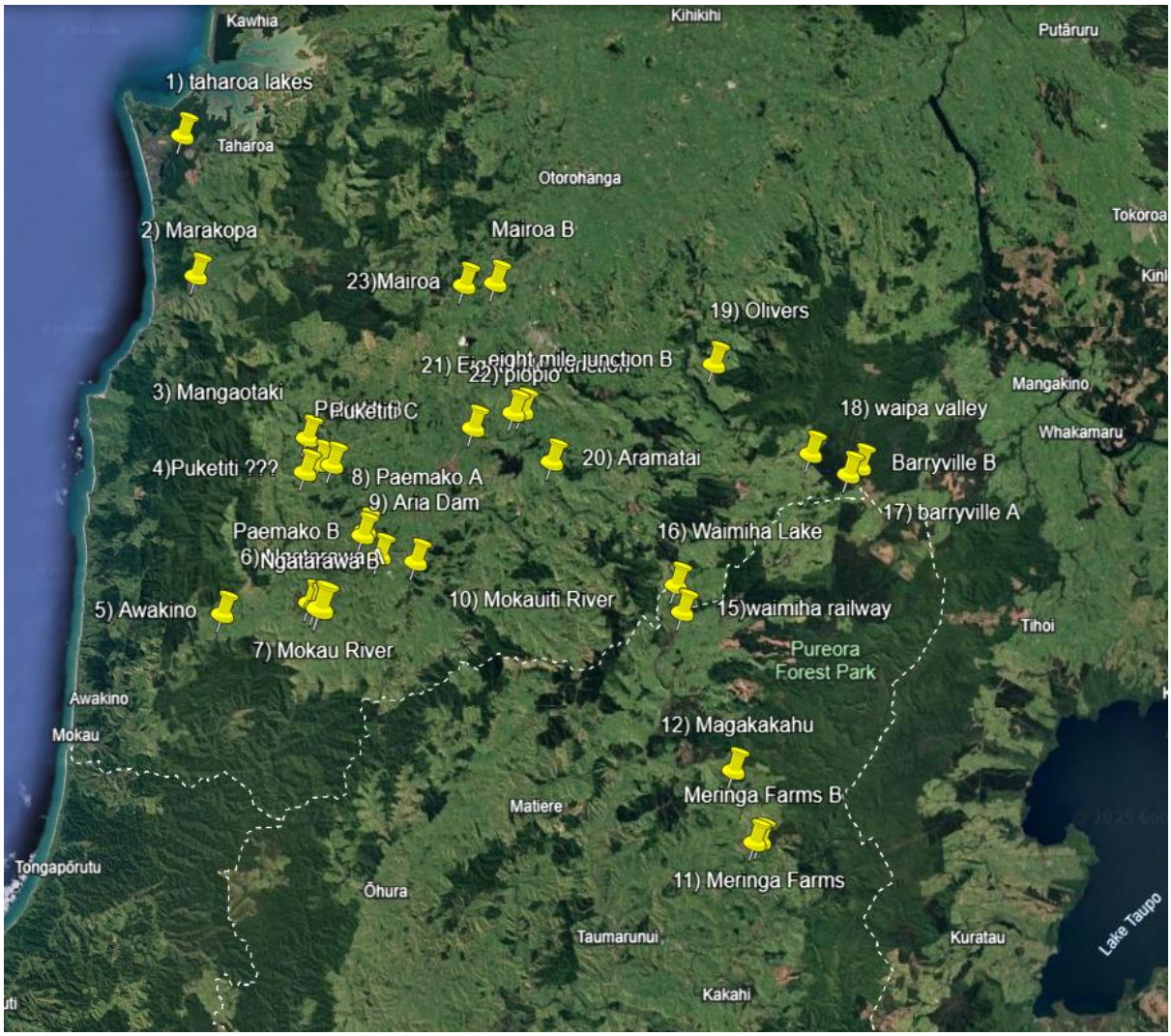

Figure 7: King Country Paradise sites.

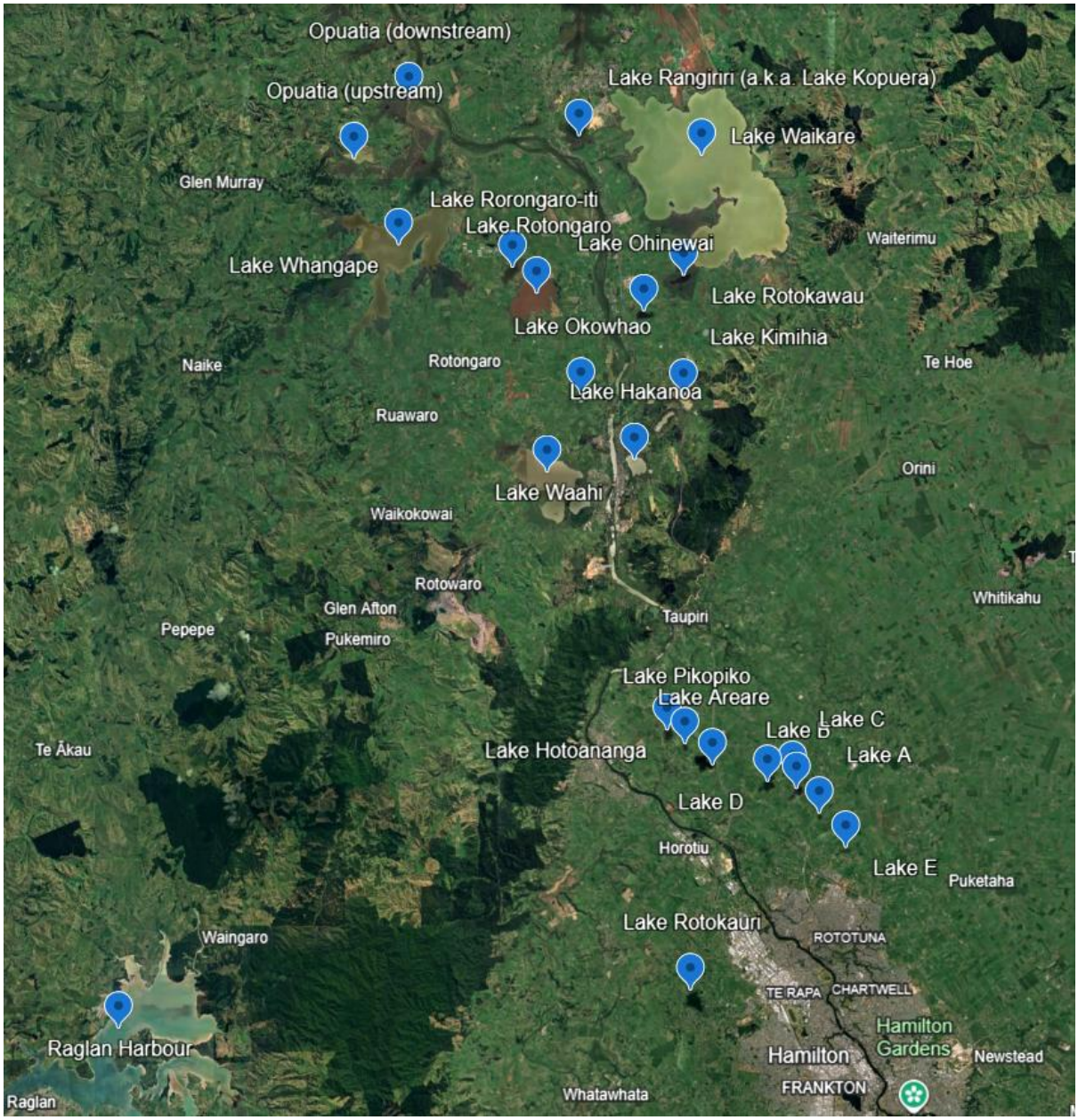

Figure 8: Central Waikato lakes and harbours black swan and geese sites (1 of 2).

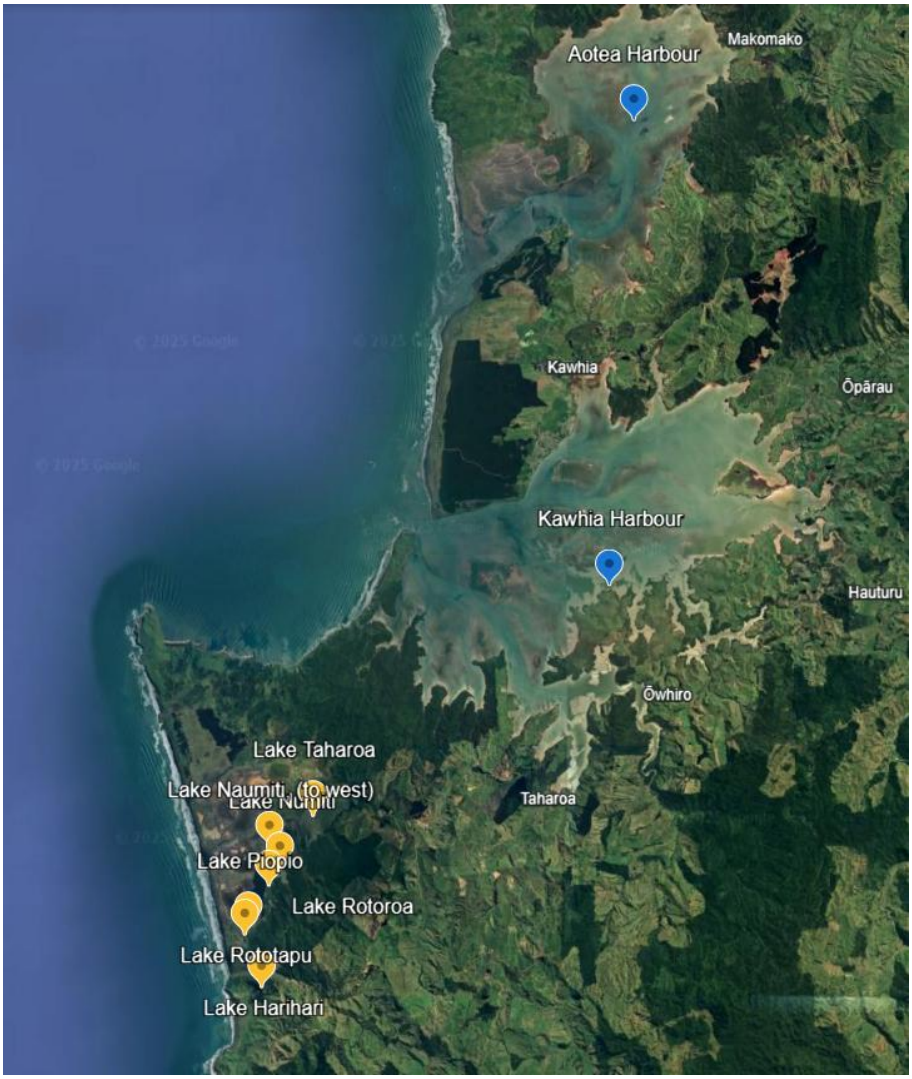

Figure 9: Central Waikato lakes and harbours black swan and geese sites (2 of 2).

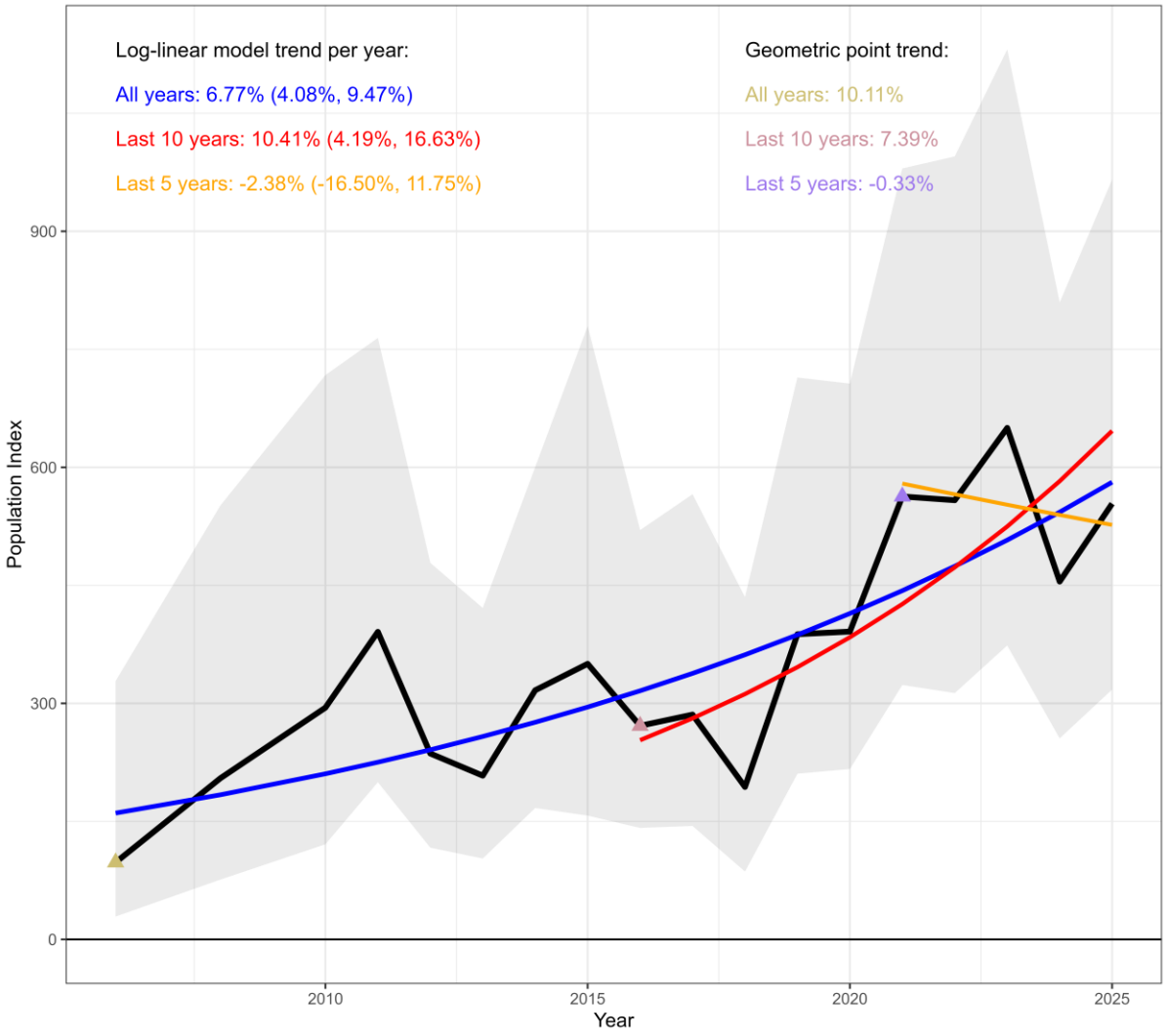

Figure 10: Estimated population index for paradise shelduck based on the north counts ***in the Auckland Waikato region only*** *(black line) and associated confidence intervals (light grey). Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses. Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.*

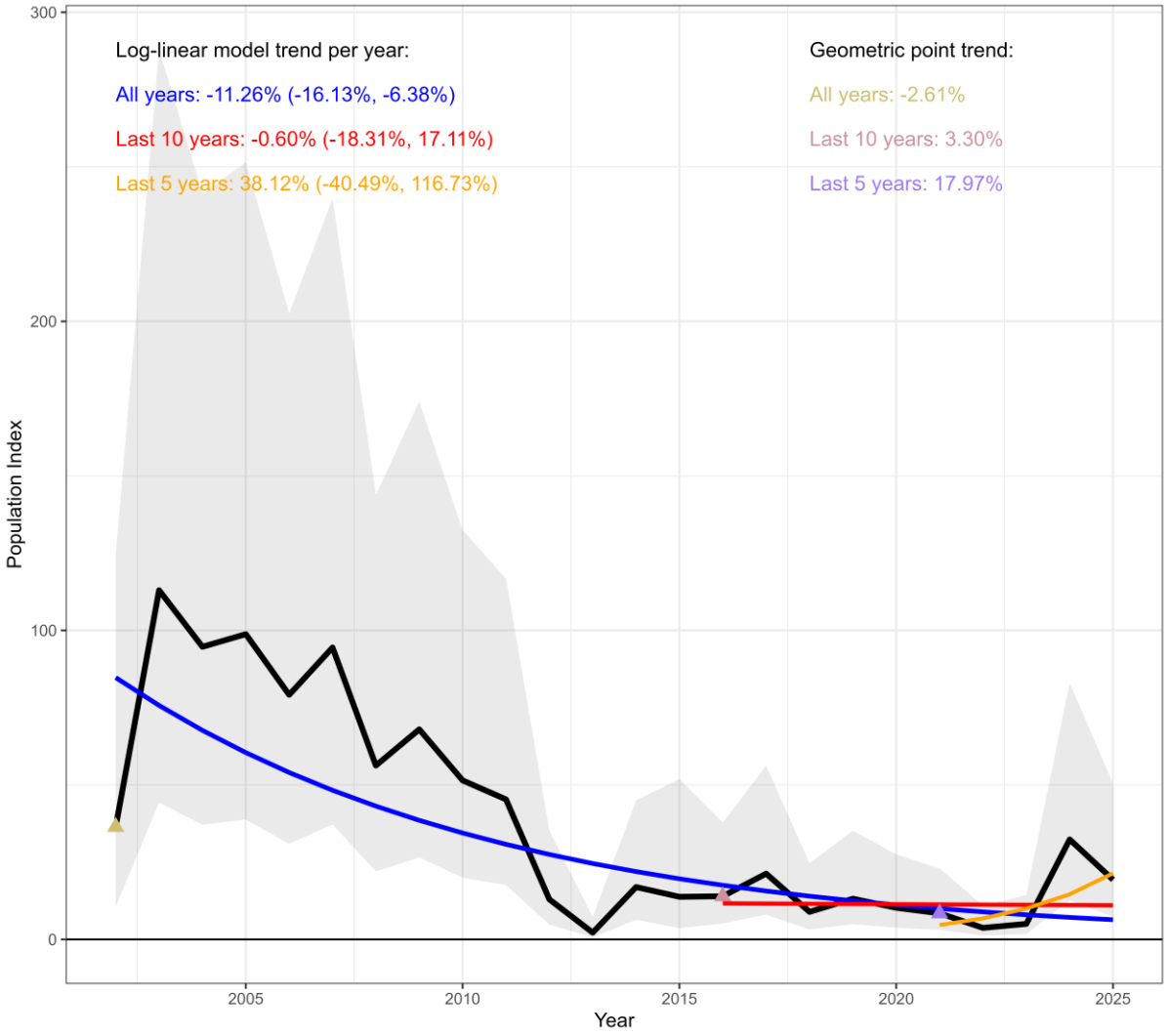

Figure 11: Estimated population index for black swan based on the North Auckland counts (and nearby Northland sites). ***Auckland Airport counts of the Manukau Harbour are excluded.*** *Log-linear models illustrating trends in indices for all years (blue), prior 10 years (red) and prior 5 years (orange) are also shown with corresponding estimates of percent annual change and 95% confidence intervals in parentheses. Geometric trends are also presented for all years (gold), the prior 10 years (pink) and the prior 5 years (purple). The starting points for these periods are represented by a coloured triangle.*

Table 1: Raw counts for King Country paradise.

Lake	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Taharoa Lakes	1020	1350	610	1139	1198	1000	825	250	270	82	20	80	130	142	52	50	60	30	260	280	530	130
Marakopa River Flats	210	0	200	90	0	130	154	50	70	300	350	350	360	350	380	490	260	280	360	130	30	180
Mangaotaki	600	475	590	150	780	1438	0	60	490	400	1550	850	600	470	440	350	350	380	910	950	750	950
Puketiti	0	0	345	920	850	752	220	40	300	100	250	300	360	300	70	100	150	70	110	50	70	20
Awakino River	0	0	0	0	0	325	300	520	290	0	75	70	75	90	80	200	40	10	40	140	290	170
Ngatarawa Rd	0	0	0	0	0	112	300	35	45	0	260	300	550	60	870	590	680	770	820	780	1150	1650
Mokau River	0	0	0	0	0	158	120	270	22	0	100	150	355	300	370	160	100	520	135	120	230	80
Paemako Ponds	0	0	0	0	0	118	380	140	220	0	10	100	345	210	110	150	195	360	240	175	350	350
Aria Dam	0	0	660	110	120	460	175	20	25	1	20	20	20	2	70	10	20	0	1	2	0	5
Mokauiti River	0	0	0	0	50	50	15	20	90	0	480	500	325	200	260	100	50	40	60	10	200	50
Meringa Farms	0	0	0	0	320	650	450	60	340	180	850	750	650	900	450	510	300	280	250	130	250	50
Mangakahu Pond	200	345	380	102	60	934	550	400	370	450	800	800	850	600	925	450	350	320	470	340	400	350
Waione	0	0	0	0	0	112	0	0	70	80	150	100	25	1	10	5	20	0	0	10	0	0
PiroPiro	0	0	0	0	180	554	15	40	15	12	20	40	30	50	6	5	2	0	0	0	0	0
Waimeha Railway	490	328	240	470	310	900	460	200	50	3	220	100	15	70	215	90	180	110	80	50	60	40
Waimeha Lake	0	0	0	0	0	641	290	500	300	550	1200	850	700	700	650	850	600	620	650	400	620	520
Barryville	800	568	765	2200	1870	2826	1040	350	800	2000	2200	1800	1600	1200	1740	1650	1350	940	1000	1400	950	1300
Waipa Valley	0	0	0	0	0	0	265	130	380	87	669	450	220	115	120	110	20	0	20	20	15	10
Oliver's Pond	0	0	0	18	130	115	235	290	200	400	550	350	248	455	460	300	550	320	300	260	10	60
Aramati	230	235	140	180	130	285	380	300	270	350	250	180	100	380	70	600	120	320	250	350	190	250
8 Mile Junction	200	245	295	700	690	1080	580	125	400	500	800	500	600	180	100	350	80	10	10	200	280	200
PioPio	0	0	0	0	0	0	0	0	100	0	740	200	70	20	190	220	250	10	20	60	112	160
Mairoa	0	0	70	220	226	351	240	55	120	200	180	200	330	120	640	350	100	60	240	50	900	200
Te Kuiti Ox Pnd	0	0	0	0	0	0	0	0	200	1300	1100	1200	850	850	1000	1200	800	650	650	1000	1100	1100
Otorohanga OX Pond	0	0	0	0	0	0	0	0	0	300	350	300	350	40	60	100	5	0	0	0	5	0

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
410	655	510	450	495	575	310	517	585	440	236	71	69	108	273	309	240	245	223	79	179
156	380	240	180	220	191	220	20	87	480	550	713	354	705	1356	1242	1504	778	833	491	631
1200	1070	1250	750	790	680	450	460	840	60	370	595	790	367	372	818	1210	720	120	522	438
900	770	570	100	280	300	15	355	315	200	260	314	296	196	439	430	287	60	390	404	235
60	110	290	40	20	40	20	55	42	15	2	74	489	150	64	159	154	596	195	154	185
1090	980	890	400	415	870	250	310	110	130	350	443	664	97	450	180	530	200	450	154	340
180	210	580	80	72	0	30	15	135	40	228	70	20	302	112	212	106	250	210	147	225
490	495	560	270	235	120	55	45	70	20	5	6	24	18	4	0	69	6	80	66	223
0	5	40	20	115	50	0	55	60	50	90	89	27	30	0	2	92	10	12	30	0
150	150	150	60	5	0	0	0	0	20	30	0	5	0	0	25	170	0	192	0	0
240	200	250	220		40	10	220	190	130	120	291	296	729	428	380	375	43	158	92	155
550	420	350	100	100	60	100	150	220	120	180	448	287	297	383	200	285	180	198	180	180
0	0	0	0	0	50	0	0	0	0	0	0	90						0		0
0	0	0	0	0	20	150	2	0	0	0	0							0		8
20	30	80	0	17	50	10	40	2	4	10	7	36	40	85	120	65	25	12	40	0
800	800	300	20	100	60	300	200	50	80	120	160									
1300	1400	1250	650	340	560	355	170	470	500	420	1092	1039	1227	807	1610	1804	900	687	161	695
0	10	20	0	8	70	1	0	0	0	0		0	8	0	2	12	0	0	0	6
10	120	280	150	475	450	20	0	10	0	40		24	0	0	0	24	15	30	0	6
600	350	290	160	250	180	140	150	30	20	90	0	80	93	98	3	18	68	22	134	120
30	10	50	60	90	90	0	20	2	0	100	87	37	45	136	153	230	170	200	136	100
300	220	530	200	110	150	380	320	220	420	180	250	351	308	159	52	35	12	0	0	0
70	20	180	220	135	20	10	30	520	190	70	336	2	87	173	82	85	36	85	80	90
820	700	950	360	495	550	610	1030	420	200	400	750	110	355	360	2000	950	950	613	470	612
0	0	10	0	5	0	0	0	10	40	45	0	0	30	16	0	0	0	0	4	0

Table 2: Raw counts for Central Waikato lakes and harbours black swan.

Lake	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Lake Rotokauri	18	56	210	220	340	197	230	110	206	120	180	190	230	170	0	10	0	3	10	0	0
Lake E	0	0	0	0	0	0	0	0	1	84	0	0	7	0	0	6	8	10	0	0	0
Lake A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	0	0	0
Lake C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
Lake D	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0
Lake Areare	0	0	10	6	10	0	0	0	0	0	0	4	0	8	0	0	10	0	0	0	0
Lake Pikopiko	0	0	5	5	0	2	0	0	36	0	0	54	10	0	0	0	10	10	0	0	0
Lake Hotoananga	0	0	11	9	54	80	60	15	7	0	40	0	40	20	40	10	10	10	0	0	0
Lake Hakanoa	0	0	0	12	55	20	12	0	26	0	2	2	10	20	15	10	20	10	10	10	40
Lake Kimihia	0	0	2	0	31	15	4	0	10	0	0	1	5	0	10	10	10	5	10	10	10
Lake Ohinewai	0	0	0	7	11	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Rotokawau	0	0	0	0	0	0	1	3	0	0	0	1	0	120	5	5	5	10	5	10	20
Lake Kopuera	0	0	0	6	0	4	0	8	1	0	0	0	0	40	10	0	10	450	50	10	20
Opuatia Lower Wetland	0	63	80	0	65	35	1	1	2	12	8	4	0	3	2	4	2	10	30	5	0
Lake Whangape	5780	5330	3494	11337	900	3160	900	870	1880	1000	500	900	1790	3235	4700	4800	4330	4440	5880	3950	3010
Lake Waikare	60	203	201	133	145	225	153	261	283	200	80	200	320	134	20	130	90	70	130	80	450
Lake Rotongaro	55	0	269	89	110	52	30	80	65	100	70	142	10	5	25	10	10	10	80	20	220
Lake Rotongaroiti	0	0	0	0	0	90	12	8	13	12	5	6	10	75	0	20	0	0	30	50	0
Lake Okowhao	0	0	0	9	85	50	390	40	82	34	60	70	50	0	50	50	50	10	10	30	10
Lake Waahi	40	205	129	160	100	50	0	110	126	112	400	140	260	540	150	450	50	300	290	260	1600
Raglan Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	20
Aotea Harbour	0	53	761	467	470	1580	1450	1210	1072	690	1230	870	1325	1262	510	1660	1010	810	1060	1920	1460
Kawhia Harbour	0	75	469	429	313	1570	1300	1025	1260	940	960	1290	534	361	365	1570	300	400	760	1650	750
Taharoa Lakes	9980	1280	1014	1497	2200	2000	1900	1940	2240	3060	1850	1100	1920	2920	1200	510	1570	2060	1910	1300	1170

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
0	10	10	0	2	0	0	3	16	2	0	24	0	0	40	0	0	0	5	4	4
0	0	5	0	5	5	0	0	0	6	0	4	0	5	0	0	0	2	5	0	1
0	0	0	0	0	0	0	5	0	4	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1	4	0	2	0	0	10	4	0	0	9	0
0	0	0	0	0	0	0	0	0	20	0	2	0	0	0	0	0	0	1	0	0
0	0	0	10	25	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0
0	0	0	10	0	0	0	8	3	8	18	6	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	4	2	2	0	3	0	0	0	0	0	0	0	0	0
0	10	10	0	0	0	0	3	0	0	0	2	1	0	1	0	0	0	0	1	0
0	20	20	0	5	5	0	7	2	15	19	14	12	0	3	13	0	20	0	0	1
8	0	10	0	0	5	0	27	80	7	5	5	0	6	2	20	4	13	20	17	15
0	0	0	0	5	0	0	2	0	25	0	0	0	0	0	5	0	0	0	12	50
4	50	30	0	0	5	18	12	7	30	0	9	3	0	36	5	21	33	41	109	60
0	0	10	0	5	0	0	110	10	20	14	138	10	35	13	6	15	18	56	50	120
0	5	5	0	0	0	0	0	10	5	5	5	12	6	0	0	0	3	30	2	6
270	130	230	110	75	85	36	155	80	81	80	44	79	218	117	75	66	135	157	115	310
60	490	190	240	140	147	65	105	227	132	200	265	314	315	208	302	316	593	1,100	451	364
50	10	50	30	10	28	110	90	5	4	0	35	9	25	4	10	7	70	79	8	90
80	5	20	10	0	20	0	60	30	22	20	18	24	62	0	60	0	0	18	3	65
10	5	10	10	0	0	0	35	0	2	0	0	0	0	0	0	0	1	3	0	0
120	80	50	0	65	245	0	50	35	12	35	158	73	10	24	42	16	33	10	102	89
30	0	0	0	0	0	0	15	20	12	15	47	7	12	0	0	1	12	0	12	3
1090	630	850	760	1210	2695	886	1725	1190	1502	1330	2112	1308	1917	1563	2198	1647	1,894	1,956	1765	1071
1230	590	570	820	1550	1605	1165	760	1415	1705	1272	1781	2674	2018	914	1506	2114	1,108	929	3125	1629
2130	2210	1280	1140	735	710	670	660	571	600	732	683	860	592	1252	725	491	291	622	1189	924

Table 3: Raw counts for Central Waikato lakes and harbours Canada geese.

Lake	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Lake Rotokauri	0	15	0	0	2	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Horsham Down Lake E	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Horsham Down Lake A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Horsham Down Lake B	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20
Horsham Down Lake C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	400
Horsham Down Lake D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Areare	10	27	0	0	0	0	26	0	0	0	0	0	0	0	0	0	130	50	50
Lake Pikopiko	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	120	0
Lake Hotoananga	0	0	0	0	0	15	0	0	0	0	0	0	0	50	10	0	0	0	0
Lake Hakanoa	0	12	0	0	0	0	0	0	30	20	34	100	30	40	20	10	0	0	0
Lake Kimihia	0	0	0	0	0	0	0	12	0	0	0	0	5	10	10	5	0	0	0
Lake Ohinewai	0	24	0	22	100	140	32	10	0	150	610	570	140	150	280	500	80	0	500
Lake Rotokawau	0	0	0	0	0	0	0	0	180	0	0	0	15	0	30	0	0	0	0
Lake Rangiriri	0	0	0	0	0	0	0	0	0	0	320	10	10	0	0	600	0	0	500
Opuatia Lower Wetland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Whangape	0	0	0	0	0	0	0	110	200	65	260	560	910	620	70	440	390	470	1180
Lake Waikare	250	340	500	138	180	550	620	1140	700	980	865	780	1025	1060	1170	315	710	1160	410
Lakeside Te Kauwhata																			
Lake Rotongaro	0	61	29	80	0	170	0	0	4	500	0	80	680	365	200	160	540	150	50
Lake Little Rotongaro	0	0	4	0	0	0	0	65	0	6	0	0	10	120	30	0	360	10	0
Lake Okowhao	0	0	0	7	340	100	0	0	0	0	0	0	0	0	10	0	0	0	0
Lake Waahi	200	210	390	350	0	380	0	220	140	145	320	385	75	700	130	210	140	80	80
Raglan Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aotea Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kawhia Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tahoroa Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
0	0	0	0	0	20	0	2	0	4	0	10	0	0	77	250	150	120	160	110	60
0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
0	0	0	0	0	30	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	10	60	60	0	0	0	5	0	0	0	0	20	20	0	17	50	35
0	0	0	15	20	20	22	2	0	0	0	0	0	0	0	0	0	0	23	0	0
0	0	0	0	25	0	0	0	9	0	0	23	0	180	0	0	0	0	0	0	0
0	40	0	0	0	45	410	10	160	260	280	50	195	0	530	256	165	220	300	300	80
50	50	20	20	60	5	0	45	0	30	0	0	0	50	110	8	50	0	15	21	32
0	0	0	20	0	0	0	25	20	30	0	10	0	0	0	6	0	0	0	21	42
10	10	0	20	0	20	0	0	120	70	120	110	0	80	307	106	130	310	260	105	220
5	20	0	0	5	10	0	0	170	250	30	0	20	42	5	0	0	3	130	30	90
140	180	450	0	80	130	160	40	30	35	50	68	33	18	189	200	45	160	30	120	470
0	0	0	300	25	10	290	65	30	50	25	5	268	60	7	70	50	50	45	60	230
100	60	80	20	65	5	0	95	120	550	250	194	331	340	600	268	128	540	60	320	375
60	10	40	0	20	25	0	0	20	30	30	20	8	40	0	21	38	12	10	40	60
990	170	946	50	135	410	55	630	500	472	270	308	909	2499	1431	987	992	1,558	145	1420	1467
220	1820	1050	490	745	665	840	315	1040	811	315	629	2002	1561	3175	874	1040	2,867	732	3129	2336
																	450	0	188	
1300	240	0	300	540	700	510	250	480	460	280	948	1215	1915	694	1266	2966	276	740	1680	790
650	10	1325	160	200	80	400	395	50	650	450	125	160	100	1591	220	1633	2,230	240	460	520
0	0	50	0	0	0	0	0	0	14	0	20	0	0	90	70	50	72	0	0	30
270	800	180	0	55	125	165	255	370	120	240	0	419	820	1082	885	1250	496	350	870	611
0	0	0	160	0	0	0	0	185	336	370	1049	1075	1281	1955	637	1233	1,361	687	1158	1673
0	0	0	0	0	12	0	125	40	15	65	60	41	130	516	450	410	605	607	1037	1263
0	40	0	0	0	35	12	132	220	270	250	1009	0	1067	1525	1046	1447	1,342	1,123	1800	1500
0	0	0	0	0	86	0	15	16	90	300	221	41	204	610	888	369	706	627	920	1635

Table 4: Raw counts for North Auckland paradise shelduck. Note: Lapsed ponds (AWx) were excluded from the analysis. Sites in the Northland region near the border were also included (Region = NL).

SITE	Region	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Wellsford Oxidation Ponds	AW	250	250	450	400	350	500	600	550	300	700	800	550	800	900	700	650	800
Tapora/Journeys End/Kaipara Harbour	AW																	
Gibbs Farm	AW																	250
Helensville Oxidation Ponds	AW																	
Parakai ponds x 2	AW																	
Lake Ototoa and surrundings	AW																	
Snells Beach oxidation pond	AW																	
Tongue Farm pond	AW																	
Omaha Beach Oxidation Pond	AW																	
Tomarata , Slipper, Spectacle lake	AW															80	0	0
Irrigation Pond Te Hana (silver hill)	AW	140	150	440	300	390	60	550	380	500	700	500	700	120	550	1000	1230	1000
Wayby Flats pond near pines	AWx											100	8	6				
Tapora Peninsula wetlands	AWx														350		300	
Kaipara Harbour environs	AWx																60	400
Pond just north Riverhead Forest	AWx											70	0					
Woodcocks Rd old & new pond	AWx											80						
Tawharanui Peninsula	AWx														255			
Snells Beach pond	AWx														400			
Pond north-west of Tomarata lakes	AWx												150					
Mangawai WWTP Northland border	AWx												800	830			1250	750
Ruakaka/Waipu Oxidation + Wilsons Dam+ Mountfield	NL	190	90	440	286	185	400	462	385	470	620	502	290	355	320	410	435	660
Brynderwyn Pond	NL							300	250	90	120	150	180	150	150	120	150	100
Mangawahi Oxidation + Worsfold ponds	NL																1100	800
Bald Rock Dams x2	NL	130	192	330	60	270	230	320	380	230	60	380	740	830	800	680	12	45
Topuni CHH	NL				100	30	40	200	200	75	100	12	0	4	25			
Kaiwaka Railway Pond and oxidation pond	NL	350	350	175	120	60	85	280	150	350	200	150	50	300	44	0	25	100
Maungaturoto Oxidation	NL	80	190	370	150	200	150	150	150	200	300	375	350	180	400	150	250	250
Taipuha(Waalkens)	NL	300	550	400	350	380	280	100	150	135	100	440	300	30	200	500	120	0

2018	2019	2020	2021	2022	2023	2024	2025
975	600	700	1727	1098	460	1050	1060
942	640	600	870	1265	1150	1123	846
1320	600	970	650	2200	1960	2200	2000
	70	50	24	0	6	0	12
		200	35	30	4	320	128
		154	230	365	178	110	83
		200	414	350	300	280	260
		12	162	280	440	620	80
		480	435	600	130	180	680
170	150	380	573	480	1490	800	641
930	1100	1100	2393	1950	1720	2400	2210
				0			
				50	0	0	0
							1
725	500	550	630	925	954	1330	882
200	200	300	120	410	260	600	760
750	600	650	650	1218	940	860	400
122	40	50	120	68	580	44	18
				70	190	40	40
50	150	275	250	650	410	260	55
350	350	400	400	750	580	720	1030
6	300	300	80	550	560	580	260

Table 5: Raw counts for North Auckland black swan counts. Note: Lapsed ponds in the Auckland Waikato region are not shown and were excluded from the analysis. Sites in the Northland region near the border were also included (Region = NL), as well as Auckland Airport counts of the Manukau Harbour.

SITE	Region2	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Wellsford Oxidation Ponds	AW		0						0					0	2	6		
Silver hill Irrigation Pond Kaiwaka/Wellsford	AW		0					6	30					0	0	0		
Kaipara Harbour Sth Tapora	AW			10000	8500	9000	7000	9000	5000	6000	4500	4000	1000	100	1450		1200	1800
Gibbs Farm	AW																	
Ponds to north/west of Parakai airstrip	AW																	
Lake Ototoa and suroundings	AW																	
Tomarata Lakes	AW																	
Ruakaka/Waipu Oxidation + Wilsons Dam+ Mountfield	NL	0	30					14	60	45	90	25	20	10	4	2		20
Brynderwyn Pond	NL								0					0	0	0	0	
Bald Rock Irrigation Dams	NL		16					2	30				10	2	14	5	6	45
Topuni CHH	NL				12	6		8	20			5	2	0				
Kaiwaka Railway Pond and oxidation	NL		120		30	25		30	30	100	40	20		44	14	12		10
Maungaturoto Oxidation	NL		0		6	0			4					0		0		
Taipuha(Waalkens)	NL		40						10			50	40	0		0		
Manukau Harbour	AW/NL														3050	1885	3884	2147

2018	2019	2020	2021	2022	2023	2024	2025
	0	0	0			11	0
	25	0	0	8	14	50	30
714	1300	839	800	241	150	3058	1400
60	36	88	60	26	120	160	1200
		2	0	6	28	40	49
		20	26	0	11	20	0
		3	3	0	65	25	10
32	3	36	0	7	94	20	30
	0	0	0	0	6	2	0
10	0	0	4	0		0	9
			0	0	10	5	0
	8	20	14	4	35	60	20
	3	8	0	0		0	0
	0	0	0	0	10	4	0
3946	4612	5156	4390	2822	7385	9388	6729

Table 6: Distribution of non-zero counts of black swan and geese for the Central Waikato lakes and harbours survey. Values of 1 (green) indicate that both the black swan count and the goose count were equal to zero. If there were long periods at sites where zero birds were counted, we may have reason to suspect that these sites were not surveyed. No evidence of this is found.

Lake	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Lake Rotokauri	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0	0	1	0	1	1	0	0	0	0	0	0	0
Lake E	1	1	1	1	1	1	0	0	1	1	0	1	1	0	0	0	1	1	1	1	1	0	1	0	0	1	1	1	0	1	0	1	0	1	1	1	0	0	1	0
Lake A	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1
Lake B	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	1	1	0	0	0	1	1	0	0	1	0	1	1	0	0	1	0	0	0
Lake C	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	0	0	0	0	0	1	0	1	0	1	1	1	1	1	1	0	1	1
Lake D	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	1	1	1	1	1	1	1
Lake Areare	0	0	0	1	1	1	0	1	1	0	1	0	1	1	0	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lake Pikopiko	0	0	1	0	1	1	0	1	1	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0	0	0
Lake Hotoananga	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	1	0	0	0	1	1	1	0	0	0	1	0	0	1	0	0	1	1	1	0	0
Lake Hakanoa	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Kimihia	0	1	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Ohinewai	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Rotokawau	1	1	1	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Kopuera	1	0	1	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opuatia Lower Wetland	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Lake Whangape	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Waikare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Rotongaro	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Rotongaroiti	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Okowhao	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	1	0	1	1	0	0	0	0	0	1	0
Lake Waahi	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raglan Harbour	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aotea Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kawhia Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Taharoa Lakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0