Monitoring Birds at Tiromoana Bush Conservation Management Area 2019

Prepared for Transwaste Canterbury by

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Tiromoana Bush Conservation Management Area showing 'Kate pond' with raupo wetland, and rank grass, gorse, restoration plantings, and hillsides with taller kanuka dominated forest patches (background) and broadleaf/scrub regeneration (mid right). Exotic pine forestry on the ridgeline and Mount Cass in the background (Photo: Jeroen Lurling).

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Executive Summary

Background

Tiromoana Bush (also known as the Kate Valley Conservation Management Area – CMA) consists of a number of patches of kanuka dominated forest located in the Motunau Ecological District in coastal North Canterbury. Bird monitoring was carried out in October each year during the period 2005–2009 and 2017-2019. The main objectives of the programme are to monitor bird count trends over time as conservation management within the CMA develops and use the monitoring results to inform best management practice to improve avian biodiversity and habitats for birds.

Methods

Modified five-minute bird counts (after Dawson & Bull 1975 and Moffat & Minot 1994) were used to monitor forest birds at 39 point locations on 13 transects in regenerating forest. Waterfowl were surveyed separately, with 10 minute visual counts at three open water areas within the CMA. For the more elusive wetland birds, standardized call playback surveys were conducted at 13 points around waterbodies and wetlands. Generalized Linear Model and Generalized Linear Mixed Models analyses were used to assess changes between years and also between the two survey periods 2005–2009 and 2017–2019, which provided more power to detect a significant difference, but also more variance. Distance analysis of density and Bray-Curtis ordination of the mean counts of all species were also used to look at forest bird changes over time. For waterfowl, GLMM and GLM analyses were undertaken comparing numbers observed during the three years 2017–2019. For crakes, records from the two species were combined and only GLM analyses were undertaken to compare numbers during the three years 2017–2019. Power analyses were carried out for forest, waterfowl and wetland birds.

Results

Overall native forest bird counts showed little change between 2005-2009 and 2017-2019. But there was a significant decline in exotic bird counts, particularly the four finch species, which declined by 52-71%. There was also a significant 24% decline observed for bellbirds. Geographically, declines in native birds were focused around transects 6, 7 and 8. Overall, silvereye and fantail mean counts increased by 104% and 52% respectively ($p<0.001$). The increase in kereru counts from zero at the start of monitoring to four in 2019, is not statistically significant, but implies it may be becoming a regular visitor or resident. The 1014% increase in tomtit counts and 72% increase in shining cuckoo counts are significant. Power analysis indicated the present study design has a reasonable level of statistical power to detect a significant change between two years for the three most common forest birds, but not for uncommon forest birds. Grouping years to compare survey periods increased power. Bray-Curtis ordination indicates that there was a change in the species composition of the forest-bird communities between the 2005– 2009 and 2017– 2019 periods, with a much larger change among exotic than native species. Overall differences in counts between the two observers were

relatively small during comparison during transition in 2017. Species richness during forest five-minute bird counts steadily increased from 15 in 2005, to 19 in 2019. Both Shannon and Fisher-Alpha diversity indices rose over the 14 years.

Waterfowl and wetland counts from 2017-2019 establish a baseline to compare future trends, particularly after predator control. Few significant changes were detected over the three years, due to high variability in counts and the flocking habit of many waterfowl. Twelve species recorded in 2019 are associated with wetlands and waterbodies, comprising 38% of the total species richness of the Tiromoana CMA. 75% of the waterfowl and wetland birds are indigenous species. All five of the threatened species were recorded in wetlands and waterbodies. An assemblage of waterfowl similar to previous years was observed. The seven common bird species observed at water bodies included five natives (black swan, grey duck, scaup, shoveler, and swallow) and two exotics (Canada geese and mallard).

The lack of bittern and fernbird calls for the third year in a row confirms the absence of these species, although bittern may be undetected rare vagrants. Four spotless crake, one marsh crake and one unknown crake were heard. These ongoing observations of spotless crake confirm the presence of a resident population. Marsh crake also appear to be resident, but likely only a single individual or pair. Average number of crakes counted at all sites ranged was 5.3 for both species combined, up from the last year's low of 3.7. The change between years is not significant, power to detect a significant difference between individual years is poor for crakes. When the next survey period is complete, comparing survey periods by combining the three years could increase power.

Power analyses suggest current survey methods and statistical analyses are able to detect moderate changes in non-flocking waterfowl, but will fail to detect even large changes for gregarious waterfowl and moderate changes for crakes. After the next survey period, grouping years to compare survey periods is likely to offer increased power for crakes and most waterfowl. Mixed model analyses may offer increased power for flocking birds, but will require greater sample sizes and more years of monitoring. Acoustic monitoring of wetland birds could be an effective way to significantly increase sample sizes and power.

Discussion

Possible causes of declines in finches and bellbirds include predation or competition. Finches and dunnock may be impacted by the significant loss of grassland and scrub habitat in the area surrounding the CMA, or the influence of weather variables. Part of the observed increase in silvereye and fantail in 2017-2019 may be due to weather variables and observer B's greater ability to hear high frequency calls, or may relate to improvements in habitat through significant understory regeneration.

The slight but steady increase in native forest bird diversity at Tiromoana Bush is a positive sign for the restoration. This increase appears to be driven largely by colonization of new species such as tomtit and kereru, and increases in rare species such as shining cuckoo. These changes may reflect an increase in habitat diversity as the kanuka forest understory regenerates in the absence of grazing. Further increases in diversity are expected with predator control. Native species diversity may provide a better long-term measure of success for Tiromoana than the abundance of the initial species. Other forest restoration projects have shown that many of the original species decline as new species establish and compete after predator control.

With ongoing regeneration, revegetation, and pest predator control, Tiromoana Bush Conservation Management Area is likely to see an ongoing increase in indigenous biodiversity values for forest birds, as well as wetland birds and waterfowl. Recommendations are made for pest control, revegetation and future bird surveys.

BACKGROUND

Transwaste Canterbury Limited have committed to a comprehensive ecological restoration project as part of the mitigation for Canterbury regional landfill at Kate Valley, which has been granted a thirty-five year resource consent. The ecological restoration project is being carried out in the designated Tiromoana Bush Conservation Management Area (CMA), located in the Motunau Ecological District in coastal North Canterbury (Figure 1). Restoration of the CMA is being undertaken to protect and enhance a substantial area of lowland forest, which is a nationally rare and poorly represented vegetation type (Norton 2004).

The main objectives of monitoring birds in the CMA are to evaluate bird count trends over time as conservation management within the CMA develops and use the monitoring results to inform best management practices to improve avian biodiversity and habitats for birds. Conservation management since 2004 has involved removal of domestic stock, baseline monitoring for vegetation and birds, annual restoration planting, weed control, establishment of a deer fence exclusion area (Norton 2012), and more recently pig control and some tracking tunnels to monitor mammalian predators.

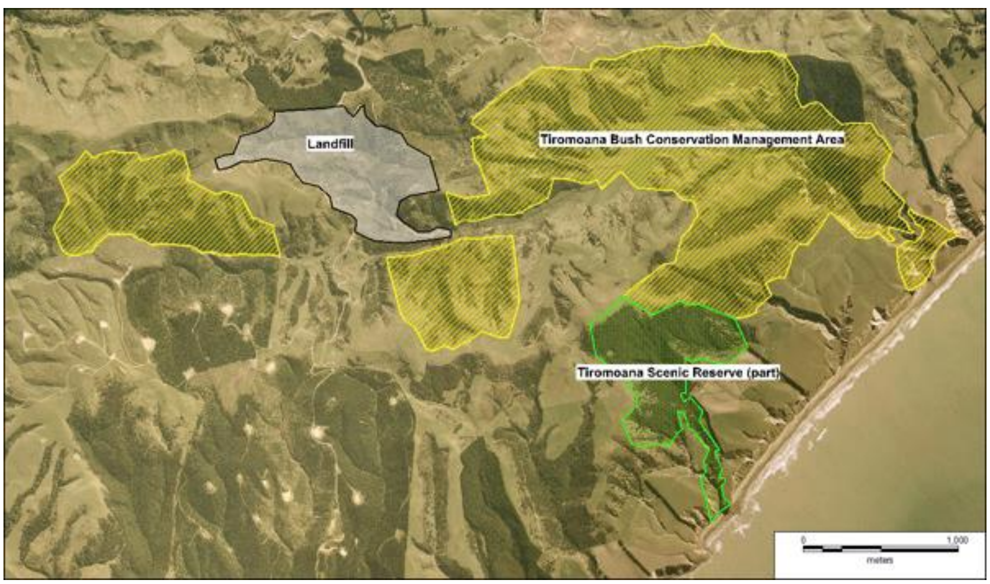


Figure 1. Tiromoana Bush Conservation Area (yellow hatched) in relation to the Canterbury Regional Landfill and adjacent public conservation land (Norton 2012).

Bird monitoring commenced in the CMA during October 2005 and was undertaken each October until 2009, providing five consecutive years of monitoring. This was the commencement of a 'pulsed' monitoring programme designed to be carried out over a 35 year period. Monitoring recommenced in 2017. This report presents the results of the third and final year of the second set of monitoring.

From late 2019, the initial stages of a more comprehensive mammalian predator control network were laid out in Tiromoana Bush CMA. Very limited trapping was initiated shortly before bird monitoring began in October 2019, but this is not expected to be of a scale or timeframe where it would have an effect on bird numbers. Comprehensive predator control will continue from summer of 2019/2020. Monitoring years 2005-2009 and 2017-2019 are considered 'before' intensive predator control treatment, and the next period of bird monitoring, will take place after and during intensive predator control. Although a fully controlled BACI design is not possible in the absence of a 'non treatment' area, bird monitoring is expected to provide a strong indication of the effectiveness of predator control.

METHODS

Field Methods

Five-minute Bird Counts

The survey method, described in Buckingham (2005), entailed a modification of the standard five-minute bird count method for estimating the relative abundance of forest birds (Dawson & Bull 1975). The modification involved using simplified distance sampling techniques (Barraclough 2000; Moffat & Minot 1994). As in previous years, bird species not typically associated with forest or scrub such as welcome swallow and yellowhammer, were not included in the surveys. All individuals of forest bird species seen or heard within 200 m of a counting site were recorded during a formal five-minute counting period. Information recorded included: the individual's species, whether it was first seen or heard, and which of three distance intervals (0–20 m, 20–50 m and 50–200 m) from the counting site the individual was in when it was first seen or heard. Rare species such as kereru and tomtit were noted even if they were not observed on formal counts.

Surveys were undertaken by during two weeks in October in each of the eight years 2005–2009 and 2017-2019. Rhys Buckingham surveyed in 2005-2009, and 2017, while Jeroen Lurling surveyed in 2017-2019. During each survey, counts were undertaken at thirteen transects, each with three count sites spaced at *c.* 50 m intervals (Figure 2).

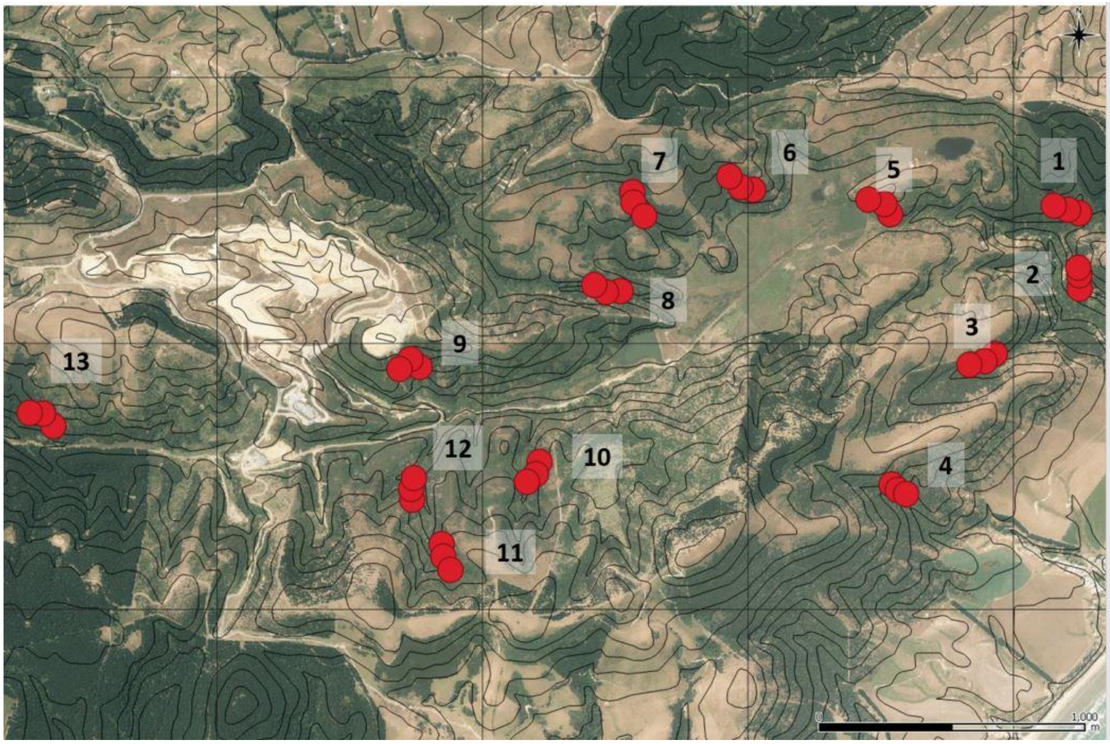


Figure 2. Five-minute bird count transects at Tiromoana Bush Conservation Area.
Red circles represent count stations.

Right truncation at 200 m gives a survey area of 12.6 ha around each count site and, with 39 sites, a total survey area of 490 ha. During the first five years, 2005–2009, distance estimates were only recorded for native species, but in 2017-2019 counts, distance estimates were recorded for all species. Each count was repeated three times, on different days, and at different times of day (morning and afternoon). Counts on the scrub transect were repeated 5 times, to increase sample size, as there is only one transect in this habitat type. A total of 123 five minute bird counts were completed between 16 and 26 October 2019.

Surveys were only undertaken between 08:00 hrs and 17:30 hrs NZDT during suitable weather conditions: without strong wind or heavy rain. Moderate wind and rain was also avoided where possible. Environmental conditions during each survey were described by scoring five variables: *Sun* (0 to 5), *Temperature* (0 to 5), *Wind* (0 to 3), *Rain* (0 to 3) and *Noise* (0 to 3) as per Dawson and Bull (1975).

During the period 2005 to 2009, monitoring was carried out by Rhys Buckingham. The current set of monitoring (2017-2019) was carried out by Jeroen Lurling (Lurling 2019), who will continue to carry out future monitoring. To facilitate comparison between the results from monitoring undertaken during the 2005–2009 period and future monitoring, both Rhys and Jeroen surveyed simultaneously but independently in 2017 (Buckingham et al. 2018).

Acoustic monitoring

As requested, monitoring by acoustic recording was not carried out with five-minute bird counts or wetland bird counts in 2019 or 2018.

Waterfowl

Waterfowl on the open water dams and ponds were surveyed by visual counts with binoculars. In 2017, 2018 and 2019, a standard survey method was used, to enable comparisons between years. Survey stations were established at vantage points with good overviews of the entire waterbody, with one point overlooking each of the three waterbodies; Kate pond, Ella pond, water supply pond (figure 3). Counts were conducted for 15 minutes and repeated at each survey station on three separate days, ensuring these replicates took place at different times of day.

Wetland Birds

The more secretive wetland birds were surveyed using call playback, the standard detection method for these species (O'Donnell, 1994). Bittern, fernbird, spotless crake and marsh crake calls were played at dusk, between the hours of 8 pm and 11:30 pm. Playback calls were downloaded from the *nzbirdsonline* website and played using a Bluetooth UE WonderBoom speaker and smartphone at moderate volume for crakes and fernbird, and maximum volume for bittern. The surveyor stood 10-15m from the speaker, so any call responses during playback could be heard. Starting with spotless crake, approximately 30 seconds of each species' call was played, followed by several minutes of listening, repeat of playback and then listening to total 5 minutes. Calls were played at set count stations to ensure full coverage of all suitable wetland habitat and to standardise effort between years (figure 3). Areas covered include the water supply pond, the small raupo pond downstream, the raupo wetland amongst the redwood plantation, *Carex secta* plantings to the east, kate pond, ella pond and *Carex secta* between these ponds. A total of 13 count stations were surveyed, and counts repeated on three separate evenings with little or no wind or rain. Environmental variables such as ambient temperature, wind speed, cloud cover and noise were scored as for five-minute bird counts. Moon fullness was also scored out of 5. The 2017-2019 surveys will establish a baseline for wetland and waterfowl species.

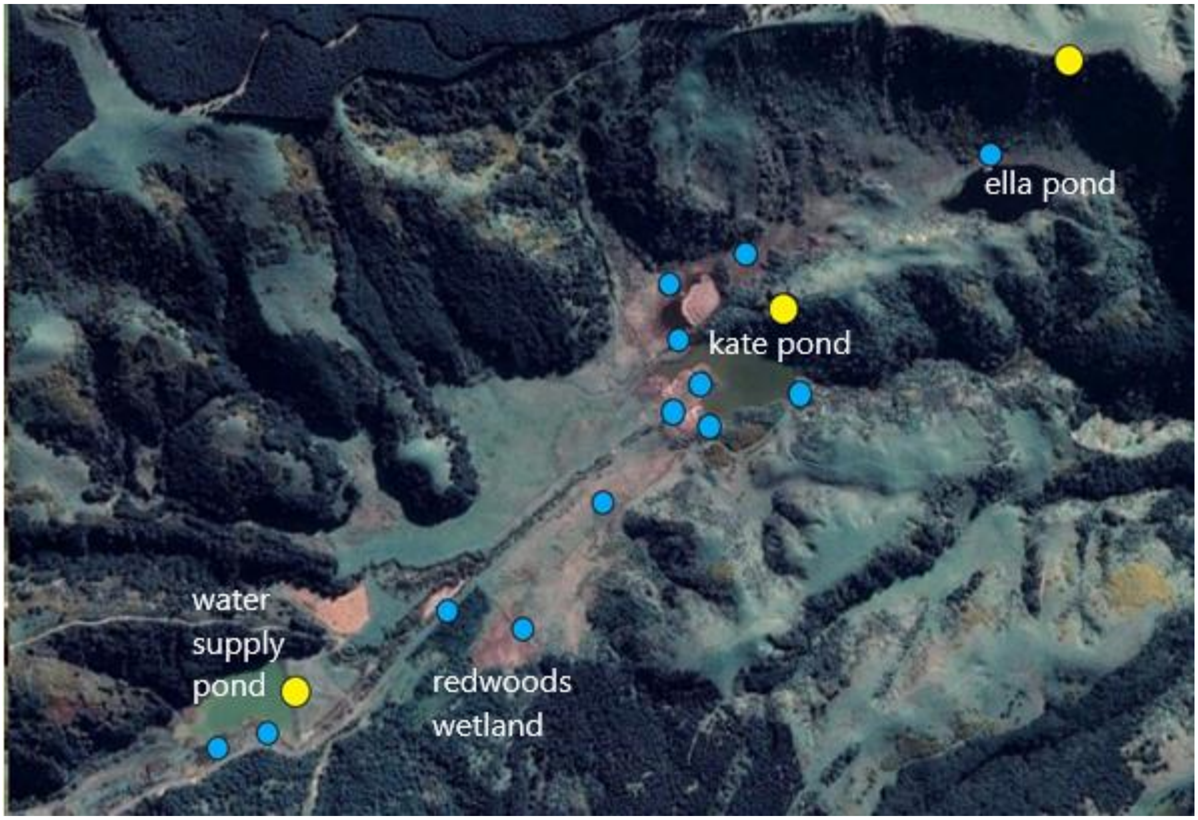


Figure 3. Locations of waterfowl visual counts (yellow circles) and wetland bird playback counts (blue circles) at Tiromoana Bush CMA.

Statistical Analysis

Statistical analyses were carried out by Dr Brian Lloyd.

Four strategies were used to investigate changes in the forest bird communities between 2005 and 2019:

- separate GLMs and GLMM's of annual pooled counts from native and exotic species;
- maps comparing mean counts during the two survey periods
- distance analysis of density
- ordination of the mean counts of all species

For waterfowl and wetland birds, GLMs of annual pooled counts were used to look at trends between 2017 and 2019.

Power analyses of forest, waterfowl and wetland bird counts were used to determine the ability of the monitoring to detect a significant difference between years.

Generalised Linear Modeling of Counts

Because both the forest-bird counts and water-bird counts comprise repeated counts at the same sites, multilevel regression models, i.e. generalised linear mixed-effects models (GLMM), were fitted to the data (Gelman & Hill, 2007). GLMMs with Poisson error distributions and log-link function were used to compare total counts between years and observers. GLMMs were implemented using the R-functions *glmer*, with individual count-site identity used as a grouping factor (i.e. random effect). For GLMM analyses, year values and observer identity were converted to unordered factors. GLMMs were not used for analysing wetland counts because of the small sample sizes.

Although generalised linear mixed-effects models (GLMM) are the best model for hypotheses testing for this type of data, there is no easy method for calculating confidence intervals around estimates from GLMMs. To obtain confidence intervals around model estimates, simple generalised linear models (GLM) were also fitted to the count data. This was done using the R-functions *glm*, for Poisson and quasi-Poisson error distributions, and *glm.nb* (R-library *MASS*), for negative binomial error distributions. Mean estimates (μ) and associated standard errors (SE) were obtained for the GLMs using the R-function *predict*. Ninety-five percent confidence intervals (CI95%) around mean estimates were calculated as:

$$CI95\% = \mu \pm t_{(\alpha=0.025,\ d.f.=n)} .SE$$

GLMs with Poisson error distributions are based on the assumption that counts are distributed randomly around the mean, whereas GLMs with quasi-Poisson and negative binomial error distributions can accommodate overdispersed data, with counts not randomly distributed around the mean. GLMs with quasi-Poisson error distributions provide estimates of a dispersion parameter. Dispersion parameter estimates close to one indicate data are randomly distributed (i.e. fit a Poisson distribution). Values less than one indicate that data are evenly distributed, while values greater than one indicate data are overdispersed, with a long-tail including more high counts than expected in randomly distributed data. When data are overdispersed, hypotheses test results and confidence intervals from GLMs with Poisson error distributions will be incorrect.

In line with the low values of dispersion parameter estimates for forest-bird counts, the confidence intervals and results of hypotheses tests obtained from analyses of forest-bird counts using the three types of GLMs (i.e. Poisson, quasi-Poisson and negative binomial error distribution) were all similar. Only results of analyses

GLMM and GLM analyses were undertaken for the twenty-one bird species observed at the Tiromoana forest-bird count sites, comparing years and observers, and was also repeated comparing the two survey periods 2005–2009 and 2017–2019, which provided more power to detect a significant difference, but also more variance.

GLMM and GLM analyses were also undertaken comparing numbers of the twelve bird species observed at water-bodies during the three years 2017–2019. Because of the limited numbers of records of crakes and difficulty in distinguishing the two species, records from the two species were pooled and only GLM analyses were undertaken to compare numbers of crake recorded at Tiromoana wetlands during the three years 2017–2019.

Power Analyses

Separate power analyses of the three count types (5MBC, waterfowl counts, wetland bird counts) were undertaken using a simulations method with 1000 simulations for each combination of the three factors: initial mean count μ, change in count Δ and sample sizes n_1 and n_2. Each simulation entailed a GLM to compare two randomly generated samples: one with sample size n_1 and mean μ, the second with sample size n_2 and mean calculated as $\Delta\mu$. For each combination of the factors power was estimated as the proportion of the one thousand simulations where the null hypothesis (H_0: $\mu = \Delta\mu$; i.e. $\Delta = 1$) was rejected at $\alpha = 0.05$. Random samples for simulating counts of forest-birds and crake were generated using the R-function *rpois* and GLMs with Poisson error distribution used for analyses of the simulated samples. However, because the error distributions of bird counts at water bodies were not Poisson, random samples for simulating the counts were generated using the R-function *rnbinom* with values of μ and the negative binomial parameter θ from actual counts of individual species. GLMs with quasi-Poisson error distribution were then used for analyses of the simulated samples.

Bray-Curtis Ordination

To investigate trends in species composition, ordination was undertaken using the R-function *vegdist* in the R-library *vegan* (Oksanen et al., 2018) to compute Bray-Curtis distances (Beals, 1984; Bray & Curtis, 1957) for all years and observers. Bray-Curtis distances are non-Euclidean dissimilarity indices with values ranging from zero, when there is no difference between samples, to a maximum dissimilarity value of one.

Diversity Indices

Fisher-Alpha and Shannon diversity indices were calculated for the forest bird 5 minute bird counts. Yellowhammer, harrier and welcome swallow were excluded, a they were judged not to be forest birds in the initial counts.

Distance Sampling Analyses

Bird densities were estimated using distance sampling methods (Buckland et al., 2004; Buckland, Rexstad, Marques, & Oedekoven, 2015) implemented in the R-package *Distance* (D. L. Miller, 2017; D.L. Miller, Rexstad, Thomas, Marshall, & Laake, 2016). The R-function *ds* was used to fit both half-normal (*HN*) and hazard-rate (*HR*) detection functions with cosine adjustments to distance data from the bird surveys. Models were compared, and best models selected, using Akaike's Information Criterion (AIC) obtained with the R-function *summarize*. Coefficients of variation used to compare the spread of results from the different distance analyses were calculated as the ratio of the width of CI95% to the density estimate, which is a more meaningful value than the commonly accepted ratio of the standard deviation to the mean.

Distance models were fitted to data both grouped into the three distance intervals originally recorded in the field (i.e. 0–20 m, 20–50 m and 50–200 m), and grouped into only two distance intervals (0–50 m and 50–200 m) created by pooling observations in the first two distance intervals. Areas in the three distance intervals around each survey site are respectively: 0.126 ha, 0.660 ha and 11.79 ha comprising respectively: 1.00 %, 5.25% and 93.75%; of the 12.57 ha total survey area around a survey site.

When distance analyses were undertaken using the three original distance intervals, the best model varied among species and years. By contrast, when only two distance intervals were used, the best model was the half-normal model for all species and years. Coefficients of variation from analyses using two-interval estimates with a half-normal (*HN*) model were lower (often by orders of magnitude) than those using three-intervals or with a hazard-rate (*HR*) model (Distance.pptx: slides 1 to 4). Consequently, only density estimates from analyses using two-interval estimates with a half-normal (*HN*) model are presented.

Distance analyses are presented for the four most common native species (bellbird, fantail, silvereye and grey warbler).

RESULTS

32 bird species (18 indigenous and 14 introduced) were recorded in the CMA during October 2019 (Appendix A). As in previous years, the most common native forest birds were bellbird, grey warbler, silvereye and fantail. Kereru, tomtit, shining cuckoo, kingfisher and harrier were all recorded in low numbers. Tomtit was recorded incidentally only. Common exotics were blackbird, song thrush, chaffinch, goldfinch, greenfinch, redpoll and dunnock.

Six species found on previous surveys (brown creeper, spur winged plover, black shag, pied shag, white faced heron, and pied stilt) were not encountered during 2019, and no additional species were recorded. Threatened species include spotless crake (At Risk: Declining) and marsh crake (At Risk: Declining). Three grey duck (Nationally Critical) were also identified from morphological features, and found breeding, but it is difficult to distinguish purebred grey ducks from grey duck/mallard hybrids without genetic analysis.

Forest birds - five minute bird counts

Trends in species counts

Overall native bird counts showed little long term change, but there was a clear decline in exotic bird counts (figure 4).

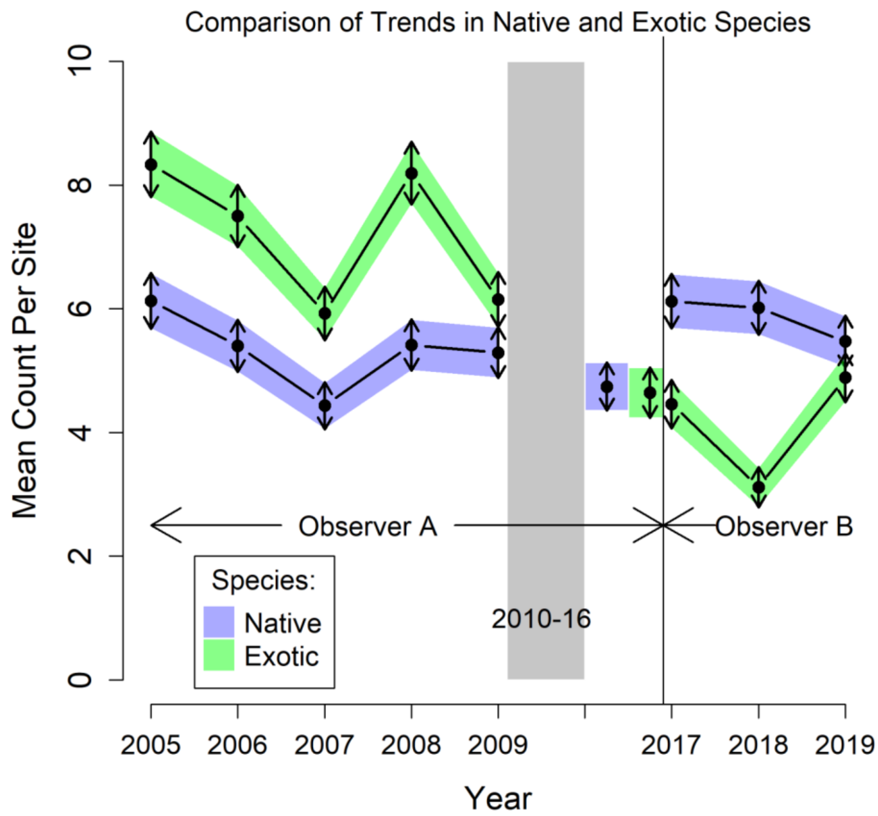
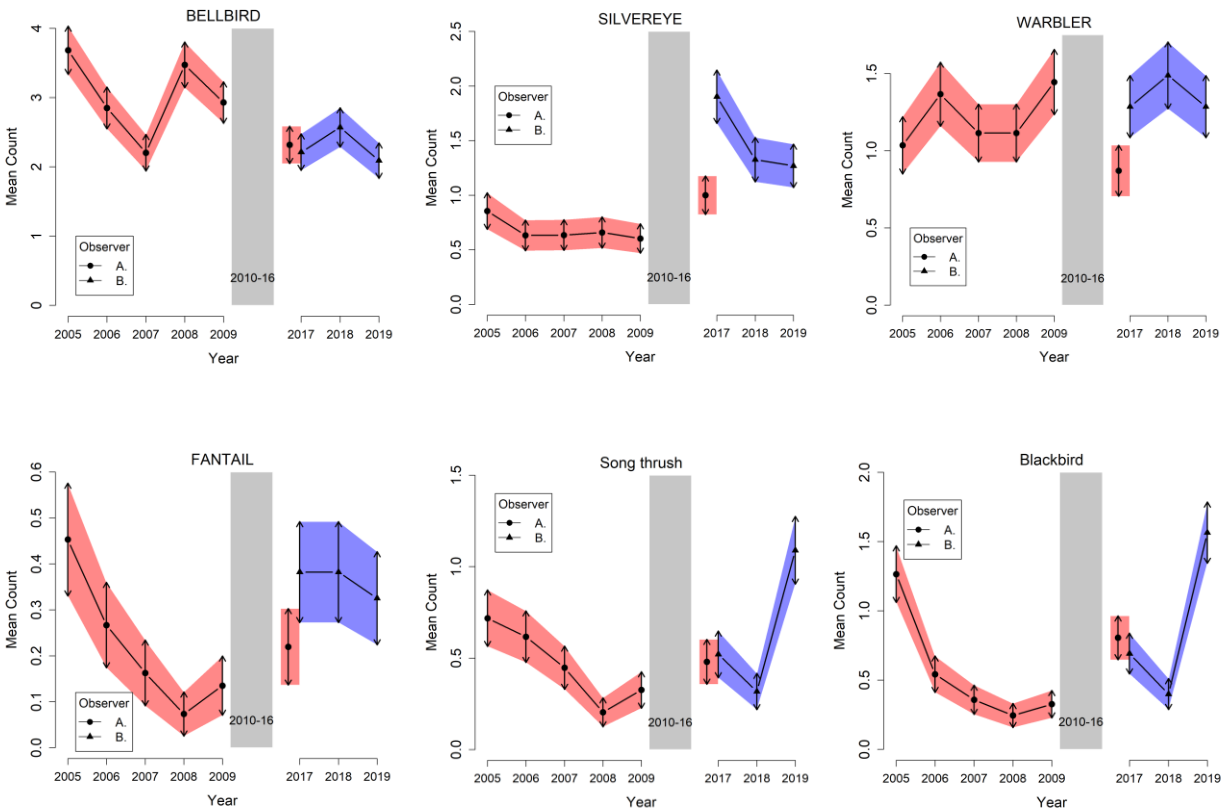


Figure 4. Comparison of trends in the mean 5-minute bird counts of native (blue) and exotic (green) species during the nine annual surveys: 2005–2009 and 2017–2019. Coloured areas and arrows show 95% confidence intervals obtained from GLMs with Poisson error distributions. There is an overlap in counts from Observers A and B during 2017.

The decline in counts of exotics is driven mainly by a decline in the four finch species, as well as dunnocks (figures 5 and 6). The 52-71% decline in mean counts of these five species between the 2005-2009 and 2017-2019 survey periods is highly significant at $p<0.001$ (table 1). Song thrush and blackbird counts increased significantly between periods, after an initial decline.

Among the natives, there was a 24% decline in bellbird counts between the two periods, significant at $p<0.001$ (table 1, figures 5 and 6). There was no significant change in warbler counts between survey periods. Silvereye and fantail mean counts have increased by 104% and 52% respectively (p<0.001). For these species, there is a possibility that this observed increase is partly due to a change in observer, and improved high-frequency hearing ability, between survey periods (Buckingham et al. 2018)



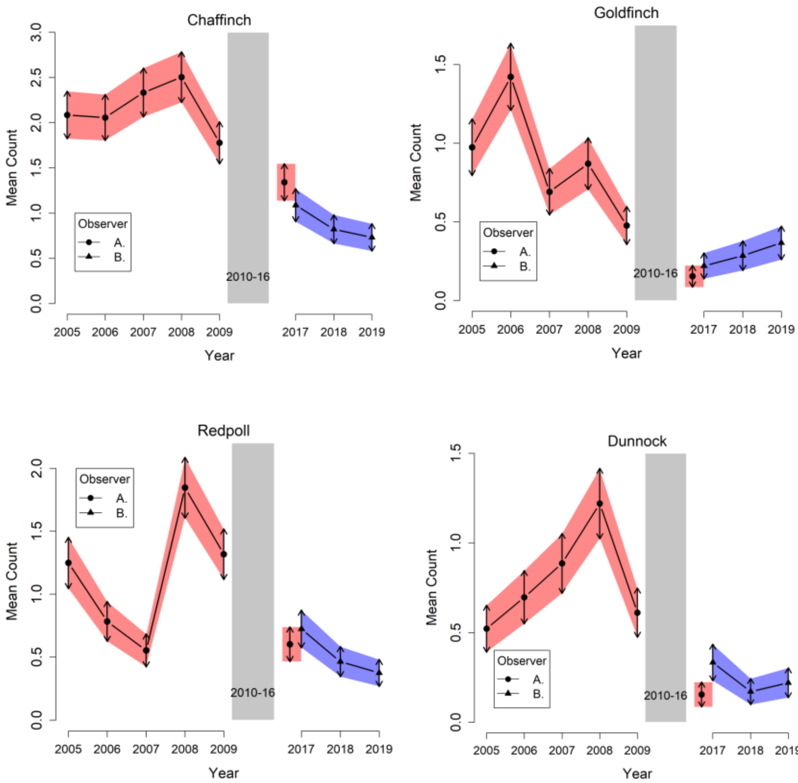


Figure 5. Plots of mean 5-minute bird count per station by year for the eleven common forest-bird species. Coloured areas and arrows represent the 95% confidence intervals around the mean counts, with confidence intervals obtained from GLMs with Poisson error distributions. Counts were undertaken by Observer A (pink shading) during the years 2005–2009 and 2017 and by Observer B (magenta shading) during the years 2017–2019, providing an overlap in counts from the two observers during 2017.

Of the uncommon native forest birds, variability in counts was generally too high to detect a significant trend, as counts depend on observations of single birds or pairs of birds. The increase in kereru counts from zero at the start of monitoring to four in 2019, is not statistically significant, but implies it may be becoming a regular visitor or resident. The 1014% increase in tomtit counts is significant at p<0.001 despite only several birds being present (Table 1).

Species	**Mean count 2005-09**	**Mean count 2017-19**	**Change**	**Significance**
SILVEREYE	0.674	1.374	104%	P<0.001
Blackbird	0.539	0.866	61%	P<0.001
FANTAIL	0.215	0.327	52%	P<0.001
TOMTIT	0.002	0.018	1014%	p<0.05
SHINING CUCKOO	0.059	0.102	72%	p<0.05
Song thrush	0.458	0.602	31%	p<0.05

KERERU	0.000	0.014	-	NS
Quail	0.044	0.053	19%	NS
WARBLER	1.217	1.232	1%	NS
KINGFISHER	0.039	0.033	-17%	NS
Starling	0.034	0.020	-41%	NS
BELLBIRD	3.021	2.297	-24%	P<0.001
Redpoll	1.151	0.541	-53%	P<0.001
Chaffinch	2.151	0.996	-54%	P<0.001
Greenfinch	0.977	0.376	-62%	P<0.001
Goldfinch	0.882	0.256	-71%	P<0.001
Dunnock	0.789	0.220	-72%	P<0.001
Magpie	0.054	0.008	-85%	P<0.001

Table 1: Mean 5-minute bird counts in 2005-2009 and in 2017-2019, percentage change and significance of the change between the two survey periods with GLM analysis. A negative percentage change indicates a decline.

Power Analysis

Power analysis indicated the present study design has a reasonable level of power to detect a significant change between two years for birds with a mean count of 1 or more per 5MBC (figure 6a). Bellbirds, silvereyes and warblers are the only natives with a mean count of 1 or more. An acceptable level of power is 0.8. There is an 80% probability of detecting a 20% increase or an 18% decrease in mean count in a subsequent year for a bird with an initial count of 4, such as bellbirds. For warblers and silvereyes, with a mean count of around 1, there is an 80% probability of detecting a 30% decline in mean count between two years. Doubling the number of counts causes very little increase in power (figure 6b), and the additional effort is not justifiable. Power to detect a significant difference was increased by combining years and comparing the two survey periods, 2005-2009 vs 2017-2019, despite an increase in variance. The results are presented in Table 1.

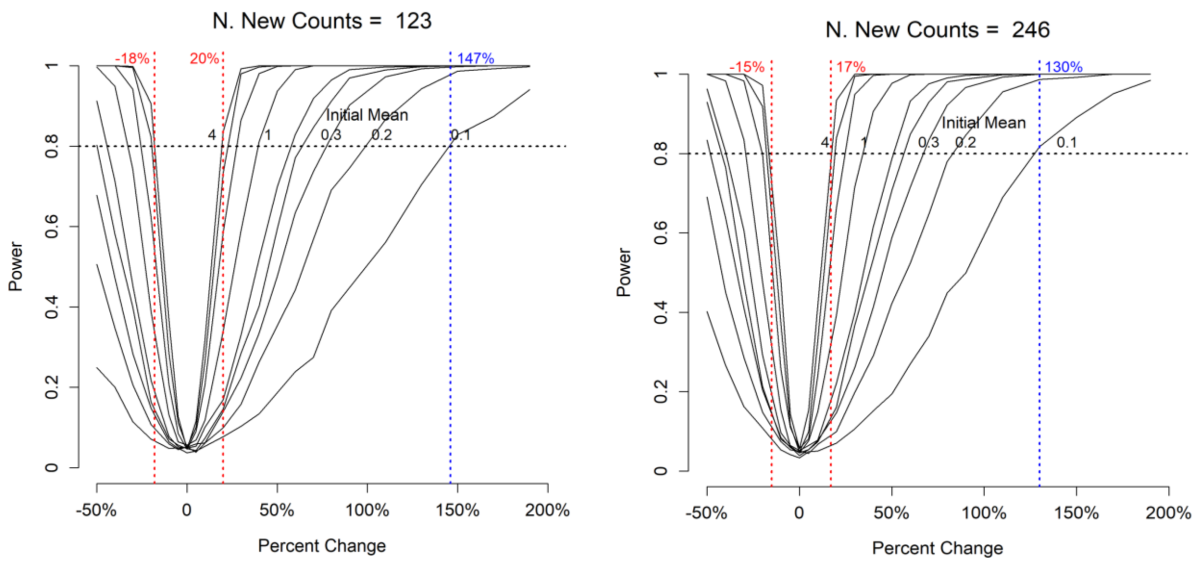


Figure 6. Power analyses using 1000 simulations for hypotheses testing for difference between individual years with GLMs using Poisson error distributions for forest 5-minute bird counts (a) using the existing sampling design with 123 counts in both years and (b) showing the effect of doubling sample size to 246 counts in the second year. Separate lines are for different initial mean count values: 0.1, 0.2, 0.3, 0.4, 0.5, 1, 2, 3, and 4.

Distance counts and density

Density estimates for bellbirds fluctuated between 2-3 per hectare, with a general decrease from 2005 to 2019 (figure 7). Silvereye density estimates fluctuated widely between 0.5 and 3.5 per hectare, with no consistent trend but higher densities in the 2017-2019 period. Fantail and grey warbler both had densities of less than 1 per hectare. Fantail showed no clear trend in density, and grey warbler increased slightly.

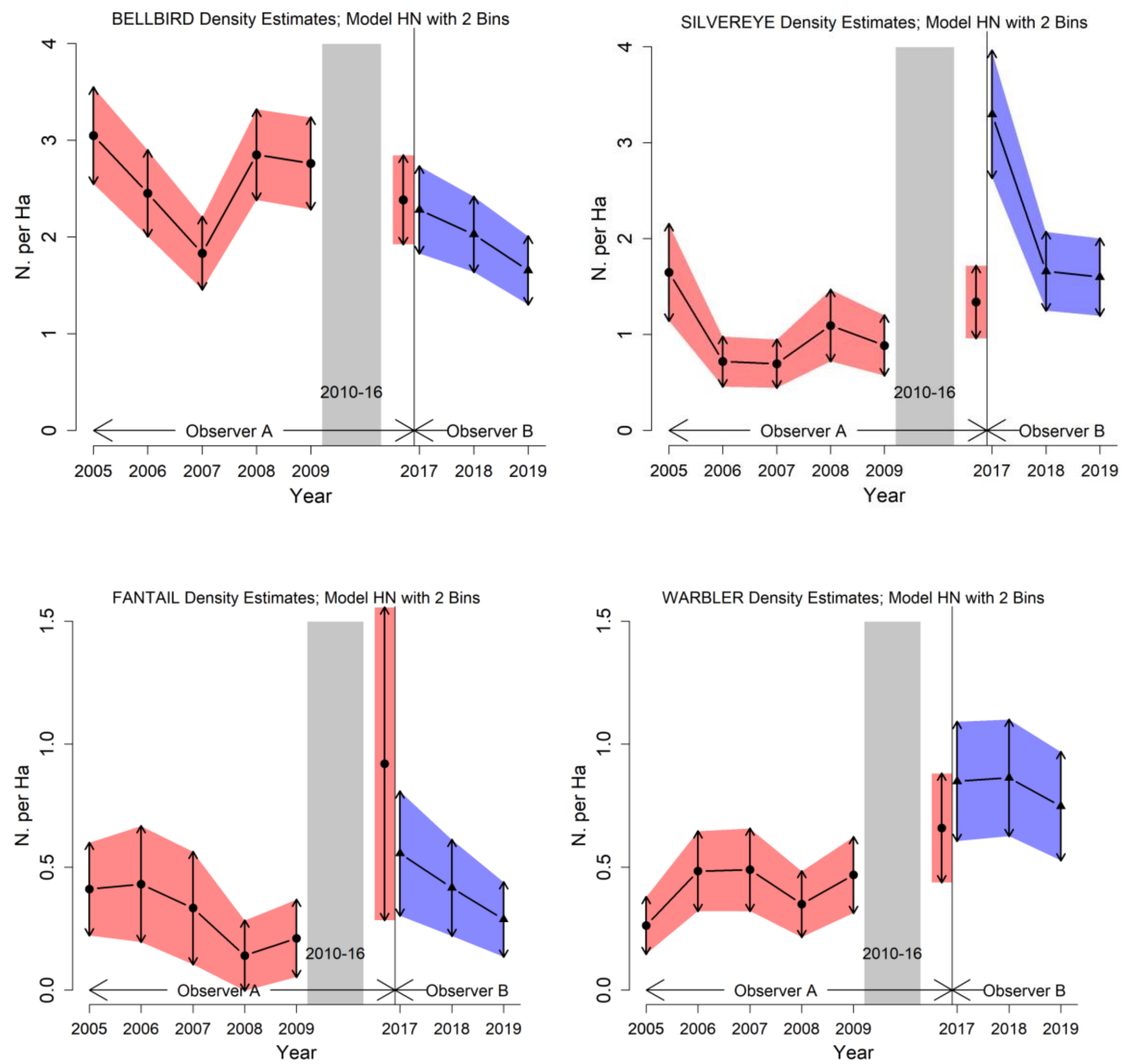


Figure 7. Density estimates, with CI95% (shaded area and arrows), from the half-normal (*HN*) distance models with two distance intervals for the native species: (a) bellbird, (b) fantail, (c) silvereye and (d) grey warbler for the nine surveys 2005–2009 and 2017–2019. Density estimates for 2017 are from both observers.

There is strong correlation (Pearson's correlation coefficient: 0.87; CI95% 0.79–0.92) between mean 5-minute bird counts and density estimates from distance sampling using two-interval estimates with a half-normal (*HN*) model. The main exceptions were once again fantail and grey warbler, which had wide confidence intervals for density estimates. Density estimates may not be reliable for these two species.

Species distribution

Geographically, transects 6, 7 and 8 (in the top middle of the maps) show the largest declines in counts of both natives and exotics, again driven by a reduction in bellbirds and finches

(figure 8).

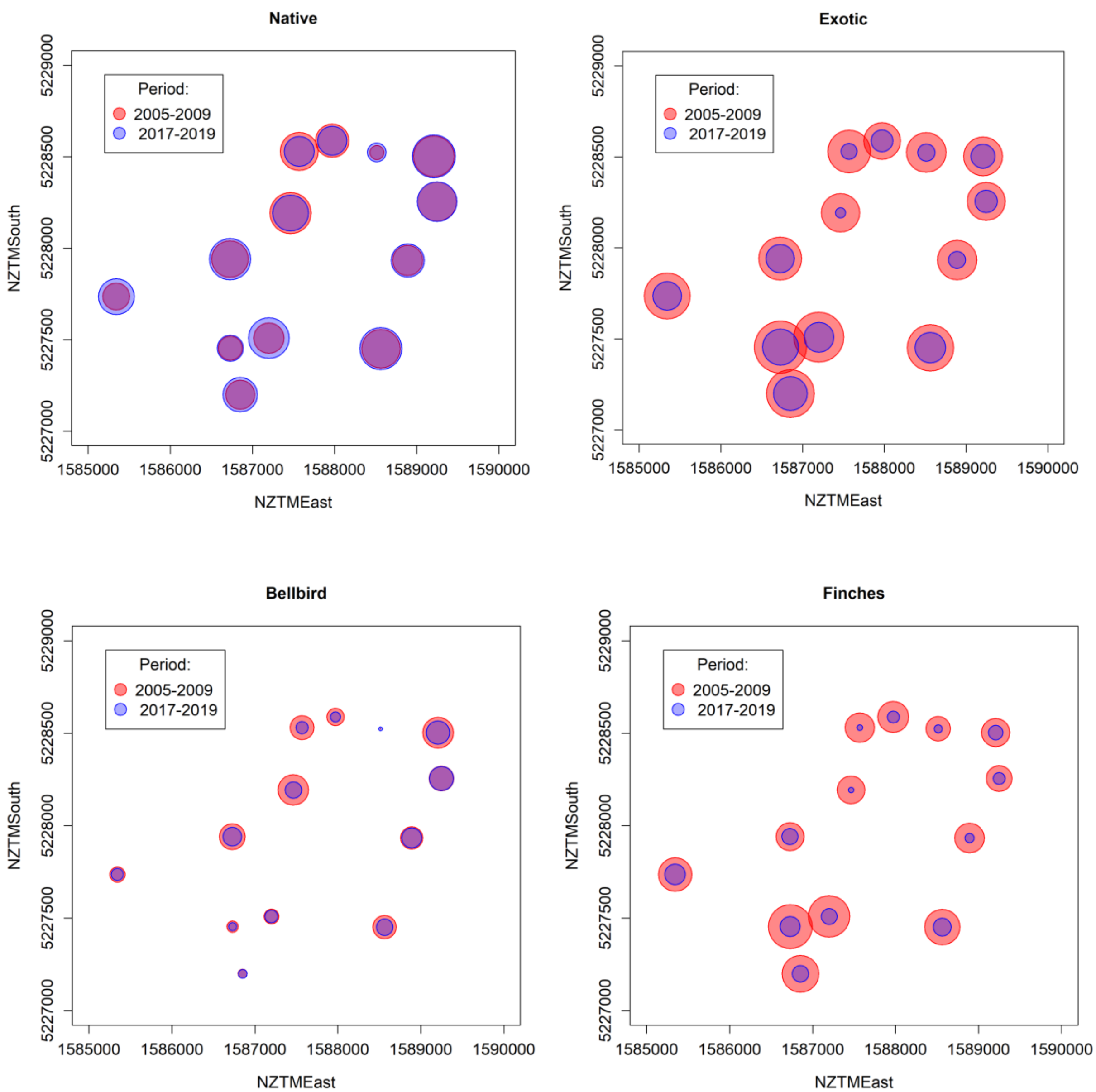


Figure 8. Clockwise from top left, maps showing changes in the geographic distribution of a) native and b) exotic bird species, c) finches and d) bellbirds, on the thirteen transects between the periods 2005–2009 (pink shading) and 2017–2019 (magenta shading). The sizes of symbols on transects are proportional to the mean counts on the transects for the periods. Note, the X-axis is compressed.

Dispersion parameter estimates for counts of the eleven common forest-bird species from GLM and GLMM analyses are close to one (Range: 0.84–1.60; Mean: 1.12), meaning most forest bird species did not flock.

Species composition and diversity

Four of the eleven most common forest-bird species were native (bellbird, fantail, silvereye and grey warbler) and seven were exotic (blackbird, chaffinch, dunnock, goldfinch, green finch, redpoll and song thrush) (figure 9).

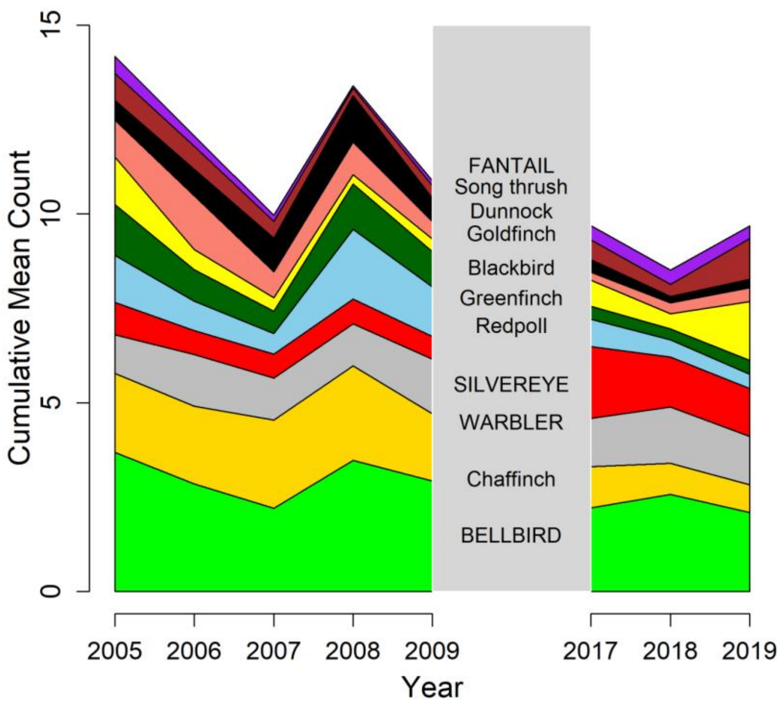


Figure 9. Changes in the species composition of 5-minute bird counts during the nine annual surveys 2005–2009 and 2017–2019. Only the 11 common forest-bird species are included in the plot. Counts for 2017 are from Observer B.

The results of multi-species analyses using Bray-Curtis ordination (Figure 10) indicate that there was a change in the species composition of the forest-bird communities between the 2005– 2009 and 2017– 2019 periods, with a larger change among exotic than native species.

For exotic species, dissimilarity values from between-year comparison between the two periods (Range: 0.32– 0.61) were considerably larger than values from between-year comparison within the two periods (Ranges: 0.17–0.25 and 0.22–0.31). Differences between periods were less pronounced for native species, dissimilarity values from between-year comparison of native species between the two periods (Range: 0.11– 0.28) were generally larger than, but overlapped, the range of values from between-year comparison within the two periods (Range: 0.08–0.21 and 0.10–0.11). The highest dissimilarity values were in 2005, 2008 and 2017, 2019.

Some of the difference in the dissimilarity indices between two periods could be a result of different observers during the two periods. This seems unlikely to be the major factor overall, because between-observer comparisons of the 2017 forest-bird counts showed differences between the two observers were relatively small, with dissimilarity index values of 0.16 for native species and 0.13 for exotic species. However, differences for some individual species were significant, with observer B recording significantly more grey warbler and silvereye due to high frequency hearing ability (Buckingham at al. 2018)

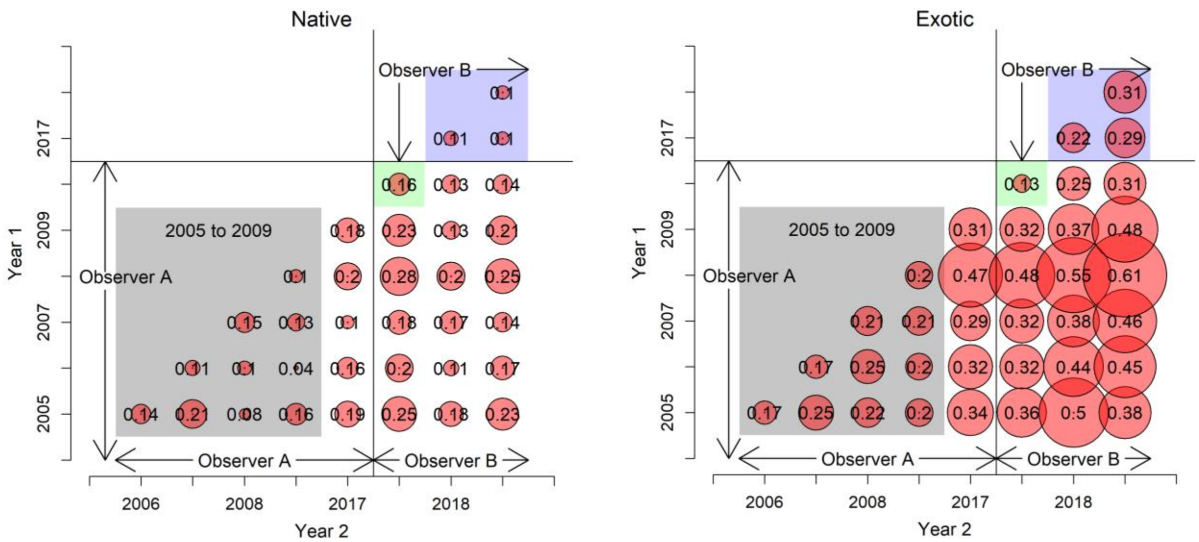


Figure 10. The results of Bray-Curtis ordination for a) native and b) exotic forest-bird species. Dissimilarity index values are provided in the symbols, with symbol size proportional to the dissimilarity index values. The lower left quadrant (grey shading) shows between-year comparisons within the 2005–2009 period. The upper right quadrant (magenta shading) shows between-year comparisons within the 2017–2019 period. Green shading identifies between-observer comparisons for 2017 counts. The rest of the lower right quadrant is for between-year comparisons between the two periods.

Species diversity of forest birds counted in five-minute bird counts in forest patches showed a slight increase during the fifteen-year period, particularly native birds (figure 11). Species richness during forest five-minute bird counts steadily increased from 15 in 2005, to 19 in 2019.

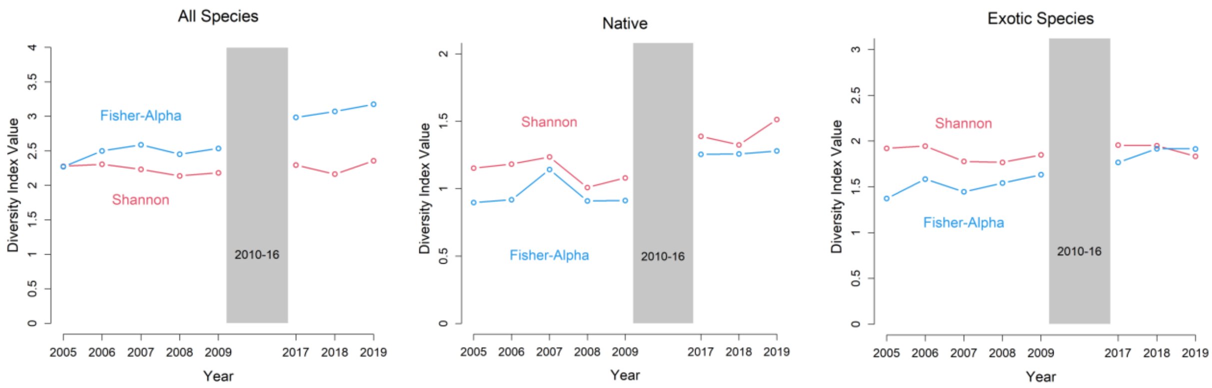


Figure 11. Shannon and Fisher-Alpha diversity indices of forest birds counted in 5 minute bird counts at Tiromoana Bush between 2005 and 2019 for (a) all bird species (b) native birds and (c) exotic birds.

Waterfowl

Diversity, composition and trends in counts

Three consecutive years of standardized counts for waterfowl and wetland birds have now established a baseline to monitor future trends. Twelve species recorded in 2019 are associated with wetlands and waterbodies (Appendix A), comprising 38% of the total species richness of the Tiromoana CMA. 75% of the waterfowl and wetland birds are indigenous species. A total of 349 waterfowl and species associated with water were counted on the three water bodies over four standardized counts. The count of 29 birds per count compares to 28 in 2018, but the higher total count reflects increased replication this year. Black swan and Canada goose were found on nests, and mallard were seen with chicks, as well as a grey duck with 10 chicks.

An assemblage of waterfowl similar to previous years was observed. The seven common bird species observed at water bodies included five natives (scaup, shoveler, swallow, grey duck and black swan) and two exotics (Canada geese and mallard). For many species there was either little change in counts between the three years, or a high variability and inconsistent trends (figure 12). However, there was a significant increase ($p < 0.05$) between 2017 and 2019 counts for welcome swallow, and a significant decrease for grey teal and black swan. 2017-2019 data is primarily intended as a baseline, and trends are expected to become more apparent with additional years' monitoring.

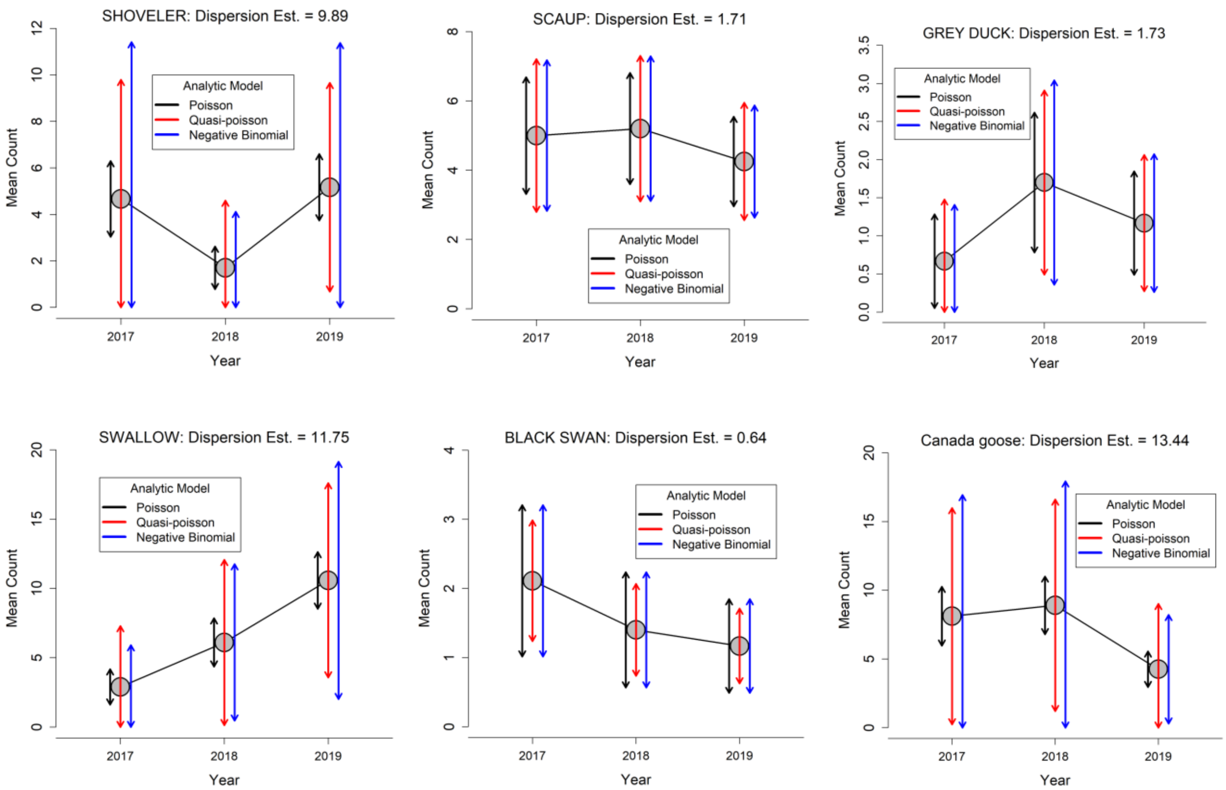


Figure 12. Trends in the mean counts of species observed at water bodies during the years 2017 to 2019. Bars with arrows represent the 95% confidence intervals obtained from GLMs with Poisson (black), quasi-Poisson (red) and negative binomial (blue) error distributions. Grey ducks may have been grey x mallard hybrids.

The GLM Dispersion parameter estimates for counts of the seven most common bird species observed at water bodies ranged from 0.64 to 13.4 (Mean: 6.06). Higher numbers indicate they are often clustered or flocking.

For the four species with highest dispersion parameter estimates (Canada geese 13.4, mallard 3.3, shoveler 9.9 and swallow 11.8) confidence intervals from GLMs using either quasi-Poisson or negative binomial error distribution are much wider than those from GLMs using the Poisson (Figure 12). Using Poisson GLMs is not appropriate for modelling counts of these four species. Between-year differences in mean counts are not significant for any of the four species.

Power analyses

For the flocking species such as grey duck and shoveler, a GLM analysis provides insufficient power to detect even large changes in the population, due to the high variability and wide confidence intervals in counts (figure 12 and 13).

For species such as black swan and scaup, which have a low dispersion parameter (they do not flock), sufficient statistical power exists to detect a 60-70% decline or a 90-100% increase between two years. Doubling or quadrupling replication provides very little increase in power using a GLM to compare individual years.

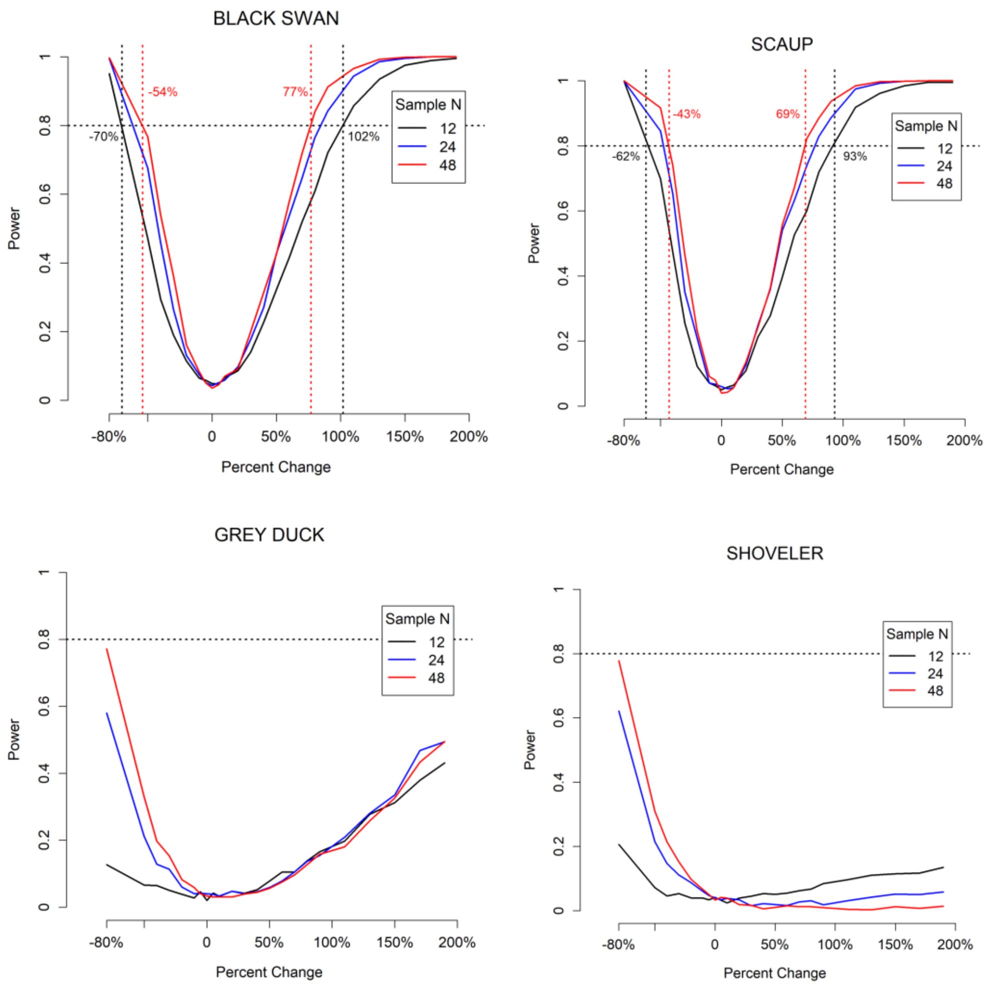


Figure 13. Power analyses using 1000 simulations for hypotheses testing of between-year variation in counts of individual bird species at water bodies assuming that counts are overdispersed and do not follow a Poisson distribution. Random samples were generated with negative binomial distribution using theta value from the species counts. Hypotheses tests for between-year variation were undertaken using GLMs with quasi-Poisson error distributions. The initial count value for each species is the actual species count in 2019. Separate lines are for power analyses using different sample sizes (12, 24 and 48), but with the same sample size used in both years.

Wetland birds

Trends in counts

As in 2017 and 2018, no bittern or fernbird were detected during playback surveys.

Thirteen spotless crake, one marsh crake and eight unknown crake observations were made over three nights. After removing potential double ups where the same bird could have been heard from different survey points, or changed location between nights, a minimum of four spotless crakes, one marsh crake and one unknown crake were present (figure 14). The actual number of crakes may be higher, particularly where birds occur close together, such as pairs. The marsh crake call was heard at Kate pond, close to where it was heard last year. The unknown crake call was a loud high pitched plaintive call from the raupo at north kate pond. Spotless crake was identified from one new location this year, the ditch/pond downstream from the water supply dam. All crakes were heard in dense raupo growing out of shallow water. As in 2017 and 2018, no crake were observed at Ella tarn, most likely due to a lack of raupo for cover.

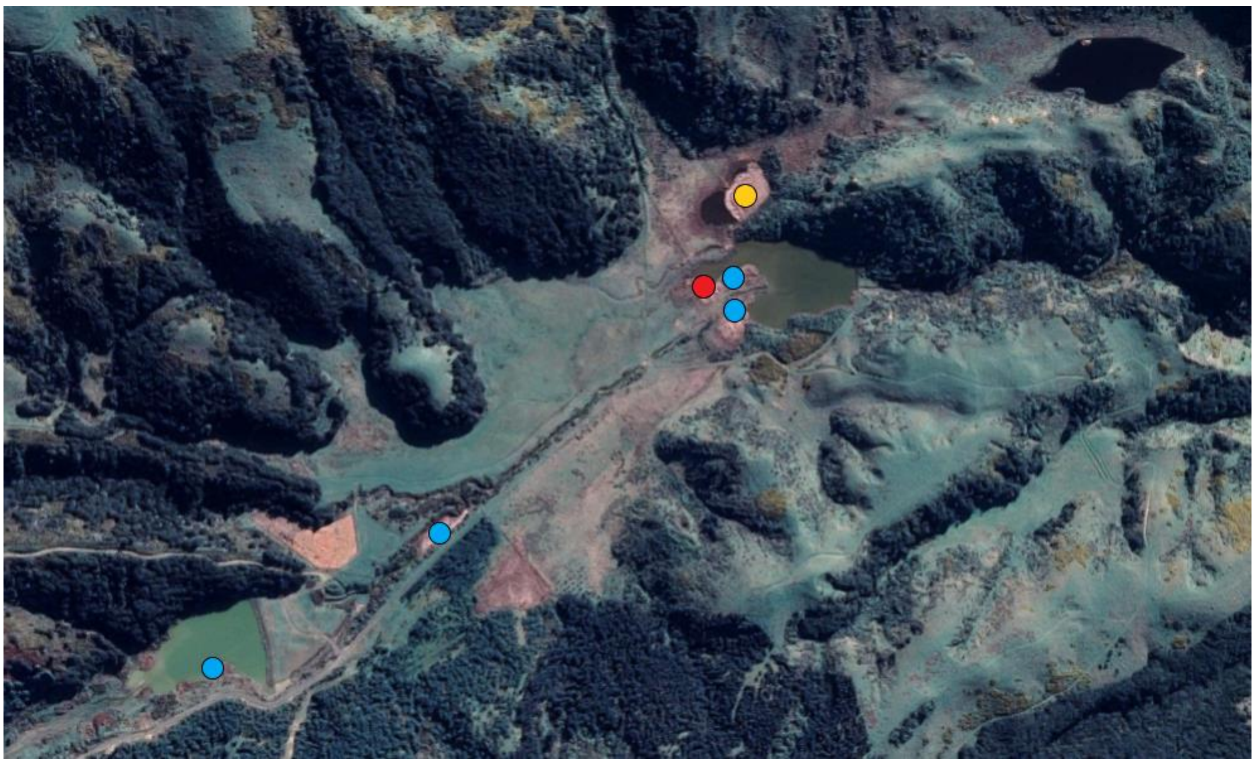


Figure 14: Locations of minimum number of crakes heard during call playback survey at Tiromoana CMA in October 2019. Spotless crake observations (blue dots), marsh crake observations (red dot) and unknown crake observations (yellow dot).

The (minimum) number of crakes detected (spotless, marsh and unknown crakes combined) at Tiromoana in one night fluctuated between three and seven over the 2017-2019 period. The mean number detected each year over 3-4 replicates and three waterbodies fluctuated from 4.7 in 2017, to 3.7 in 2018 and up to 5.3 in 2019 (figure 15). Confidence intervals are wide and overlap, indicating no significant change between years.

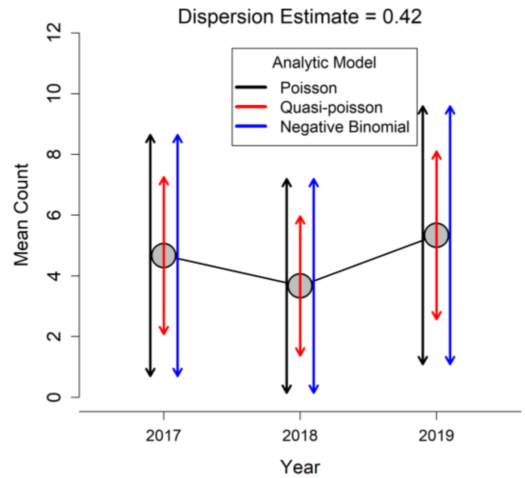


Figure 15. Trends in the mean counts of crakes during the years 2017 to 2019. Bars with arrows represent the 95% confidence intervals obtained from GLMs with Poisson (black), quasi-Poisson (red) and negative binomial (blue) error distributions.

Power analyses

Power analysis of 2017-2019 crake counts suggests power to detect a significant change between individual years is poor (figure 16). Sample size is low (n=3) when combining survey sites and using minimum number of birds detected across all count stations in one night. With an initial mean count of 5, a 138% increase is required to have an acceptable (80%) probability of detecting a significant difference between two years. Counts need to be increased to 30, to have an acceptable probability of detecting a 34% increase, or a 28% decrease between years. When the 13 survey sites are treated as separate replicates and not combined, sample size is increased (n=39). However, the initial mean then drops dramatically to 0.38 and variance is also high so power remains low.

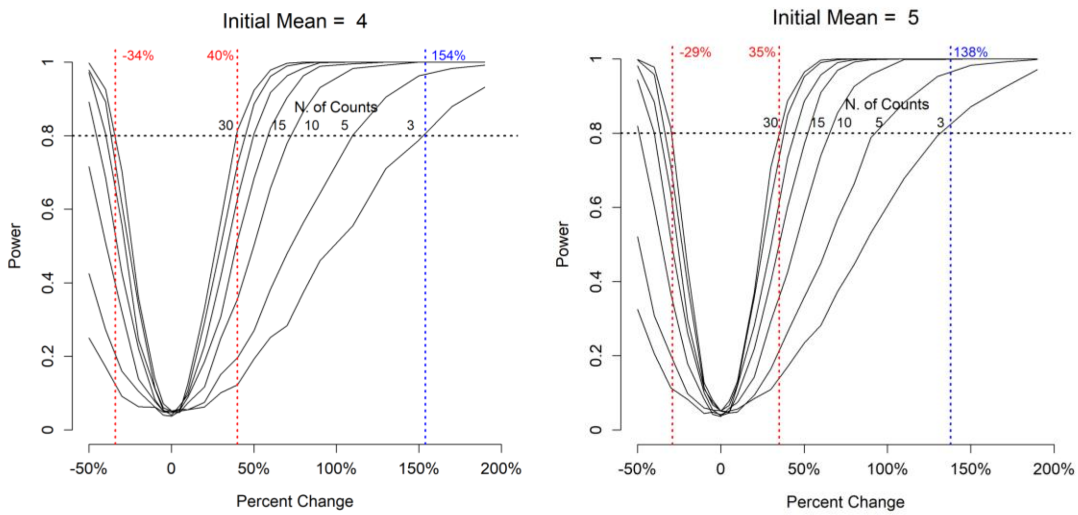


Figure 16. Power analyses using 1000 simulations for hypotheses testing of between-year variation in counts of crakes assuming that counts follow a Poisson distribution and are not overdispersed. Random samples were generated with Poisson distribution with initial mean counts of 4 (a) and 5 (b). GLMs with Poisson error distributions were used to test for between-year variation. Separate lines are for power analyses using different sample sizes (3, 5, 10, 15, 20, 25 and 30), but with the same sample size used in both years

Pest Mammal observations

Incidental observations of pigs in 2019 included 8 adults and 6+ piglets (Appendix B). Two goats were heard at transect 9c on 16 October, and a number of ring barked totara plantings were seen around transect 6, 7 and 8. This may have been done by goats or deer, this year or last.

A slip has created a gap under the fence at the northeastern forestry block, at approximately NZTM E 1589267 N5228565. It is large enough for goats, pigs and possibly deer to enter the CMA. Some tree branches were placed in the gap to slow entry of feral animals, but it needs to be repaired, if not already done.

DISCUSSION

Forest bird five minute bird counts

Trends in counts

It is a promising sign to see sustained moderate to large increases in newly established or rare species such as tomtit, kereru and shining cuckoo, as well as increases in two common species, silvereye and fantail. These increases may reflect the marked increase in understory vegetation cover, height and diversity in the 15 years after removal of grazing stock. Observer differences may contribute to these observed increases in some common forest birds. Observer B counted significantly more silvereye and grey warbler than Observer A, and attributed them to closer distance bands, likely due to observer A's loss of high frequency hearing (Buckingham et al. 2018). Weather variables may also play a part (Buckingham et al. 2018).

The ongoing and significant shallow decline in bellbird counts between 2005 and 2019 is of some concern, as bellbirds are the most common native bird recorded during five-minute forest bird counts at Tiromoana. The moderate decline in exotic bird counts, particularly finches and dunnocks, is striking but of less direct concern as the restoration aims to restore native biodiversity. There is no obvious reason for these declines. Possible factors include observer differences, weather, predation, competition or habitat change.

If the declines in counts reflect an actual decline in population densities, the results of studies elsewhere indicate that mammalian predators are the most probable causal agents (Elliott et al. 2010; Elliott & Suggate 2007; Innes et al. 2010; Innes et al. 2015; O'Donnell 1996; O'Donnell & Hoare 2012). However, it is unclear as to why finches and bellbirds would be more affected by predation than the other native bird species. Generally exotics are considered less susceptible to mammalian predation due to co-evolution.

Competition for seeds by mice is another possibility. Chaffinches, goldfinches, greenfinches, redpolls and dunnocks are found primarily in open grassy areas, scrub and forest edges, feeding near the ground on grass and weed seeds, and invertebrates (Reader's Digest Services 1985). Large increases in rank grass and gorse associated which occurred shortly after removal of grazing animals may lead to irruptions of mice. Tracking tunnel data will provide more clues in future.

Loss of habitat may have contributed to the decline in finches and some other exotic passerines. In the last 15 years, grassland habitat has decreased markedly in the area surrounding Tiromoana CMA, within less than 1km of most 5MBC stations (figure 17). Grassland has been replaced by exotic pine and macrocarpa plantations and bare earth (landfill). Gorse and scrub cover has replaced a small area of grassland in the CMA, and initially also increased in plantation blocks but is now being shaded out and excluded. Chaffinch, greenfinch and redpoll can inhabit pine forests, but it is not their preferred habitat (Reader's Digest Services 1985).

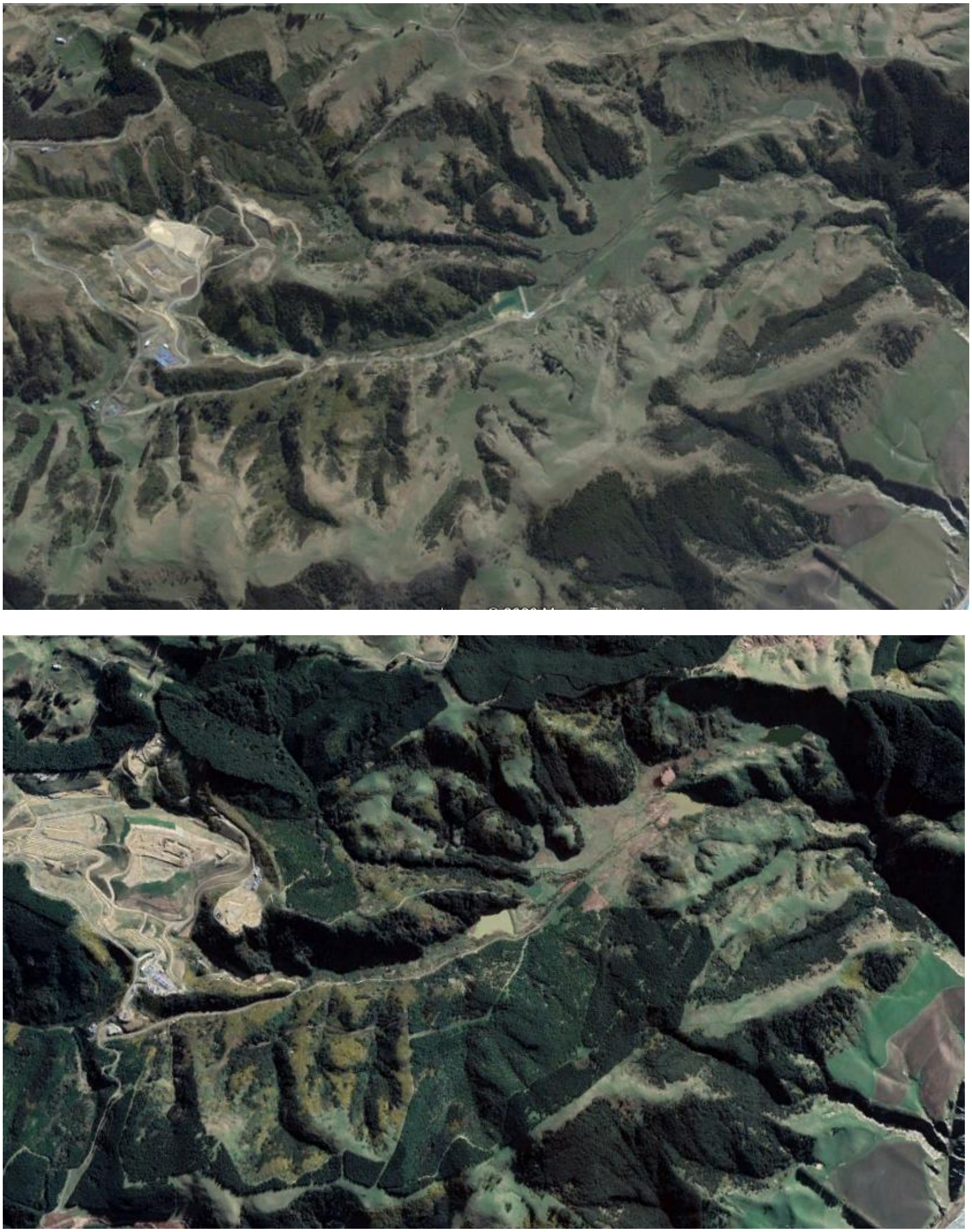


Figure 17: Aerial imagery of Tiromoana CMA survey area in 2006 (upper) and 2019 (lower), showing changes in landcover, particularly pines and landfill bare earth.

It is possible that trends in counts are also influenced by changes in of birds. 95-98% of birds detected in five-minute bird counts at Tiromoana are heard rather than seen, so call rates have a large influence on detectability. Weather variables have been known to influence call rates, but the affect can be positive, negative or non-significant depending on the bird species and other variables (O'Connor & Hicks 1980, Ellis & Taylor 2018). Significant impacts of weather variables tend to occur mostly at extremes of wind and rain and temperature (Ellis & Taylor 2018). Surveys at Tiromoana are not carried out at times of high wind and rain, and seldom during moderate wind or rain. It appears unlikely weather is a major factor, but it may have some influence. Birds may be present in similar numbers, but call more in warm or sunny spring weather, or be more detectable in the absence of wind or rain. 2005 and 2008 were El Nino years, with a warm, dry and settled spring in Canterbury, and noticeably higher finch counts (NIWA 2020). 2007, 2009 and 2018 were La Nina years, particularly cold, wet and windy in North Canterbury, with lower call rates for many species. Quantitative statistical analysis of the effect of weather variables on bird counts was carried out in 2017. In separate GLMMs for each of the 11 common species (2005 to 2017), wind and rain were associated with a significant reduction in counts for most species, but neither was significant for warbler and silvereye. However, analyses indicated this influence could be an artifact arising from differences in the weather scores between years, not a direct influence of rain or wind on counts This analysis should be repeated when the next period of monitoring is complete and additional data available.

Without a control site, it is not possible to definitively determine whether trends in bird counts are due to site specific changes (eg. bush restoration or future predator control) or more widespread factors, such as changes in weather, climate or predation. National or regional long term survey data could be investigated to obtain a rough idea of background trends. Two such surveys are the annual NZ garden bird count, and the Department of Conservation Tier 1 monitoring program. The NZ garden bird count recorded slight to moderate declines in silvereye, grey warbler and fantail (-16 to +42%), and little or no change for bellbird and kereru from 2007-2016 (Landcare Research 2016). Finches species varied between shallow increases and shallow to moderate declines (-26 to +14%). These trends are inconsistent with findings at Tiromoana. These counts occurred mainly in urban gardens in winter, which is likely to represent a sampling bias. There are indications the declines in counts of many birds in gardens in winter are due to rising temperatures reducing the birds' need to enter cities and gardens to forage. Department of Conservation Tier 1 monitoring has few bird count plots nearby and at this stage most have one repeat survey, which is insufficient for trend comparison.

Inconsistencies in trends over time and between species indicate there are likely to be a combination of factors interacting. Additional bird count data, associated weather data, and predator control data from the next monitoring period may help clarify these factors.

Composition and diversity

Bird species composition at Tiromoana Bush is similar to that of monitored forest remnants on Banks Peninsula. The most commonly counted native species were bellbird, silvereye and grey warbler (Schmechel 2010). These species appear to be most tolerant of degraded kanuka habitats and higher predator abundances. Fantail, brown creeper and Kereru were moderately abundant, followed by infrequent or rare counts of shining cuckoo, tomtit, rifleman and tui. Nearby Department of Conservation Tier 1 monitoring plots in north Canterbury also indicate a similar bird species composition to that of Tiromoana Bush. Forested plots tend to have falcon and morepork as well, and tomtit are more common (Department of Conservation 2020).

The slight increase in native forest bird diversity at Tiromoana Bush is a positive sign for the restoration, and appears to be driven largely by increases in rare species. These changes likely reflect an increase in habitat diversity as the kanuka forest understory regenerates in the absence of grazing. Further increases in diversity are expected with predator control.

Comprehensive predator control is important for birds such as tomtit, brown creeper, robin, tui and falcon to fully re-establish, and necessary for more sensitive species such as riflemen, fernbird and bittern to establish naturally or by reintroduction. Where cats, mustelids and possums are controlled, rodent irruptions may ensue and impact sensitive bird species if not controlled as well.

For degraded forest remnants with high predator abundance, an increase in native bird species diversity is potentially a better indicator of restoration success than an increase in abundance of the original species. Silvereye, grey warbler, fantail and bellbird are more resilient to high predator abundance, and are common in regenerating scrub and forest with no predator control. The smaller birds appear to do well with predator numbers through placing their nests on thinner branches (Fea 2018) After forest restoration and predator eradication at Zealandia, Orokanui and other sanctuaries with predator control and eradication, many of the species present before predator control actually decreased significantly ((Miskelly 2018, Fea 2018). There were indications that these dominant species may have been partly outcompeted as more predator-sensitive natives established. Both the addition of new species (from reintroductions and natural recolonisations) and reduction in dominant species caused a marked increase in species diversity.

With ongoing revegetation, regeneration and best practice predator control, Tiromoana Bush is likely to see an increase in biodiversity values for forest birds but may see a decline in the species dominant before intensive predator control.

Waterfowl

Waterfowl and wetland counts from 2017-2019 establish a baseline to compare future trends, particularly after predator control.

The significant decline in grey teal and black swans observed between 2017-2019 is not of great concern, due to the short timeframe and low counts, as well as the high mobility and gregarious habit of these species, particularly teal. The observed declines may be by chance, and additional monitoring is needed to establish long term trends.

Power to detect a significant difference in counts between years ranges from reasonable to poor, due to high variability in counts and the flocking nature of some species. When more data is collected, comparison of survey periods (grouping several years) rather than comparing individual years may increase the power to detect a significant difference, especially for flocking species. However, for species not detected consistently between years, this approach may also increase variance, which reduces power.

A mixed model may provide a better approach for statistically modelling counts of gregarious or flocking bird species at water bodies, to compare trends. In a mixed model, the probability of a species being present would be modelled as a binomial distribution, and when a species is present the number of individuals would be modelled as a Poisson distribution. Unfortunately, a mixed model is not practicable with the small sample sizes reported here.

As waterfowl counts are quick and easy, they should be carried out whenever passing by one of the waterbodies, to increase sample size and statistical power, aiming for at least 5 replicates per year.

Wetland birds

The lack of bittern and fernbird calls for the third year in a row confirms the absence of a resident population of these species. Bittern are highly mobile and secretive, so the possibility cannot be ruled out of the occasional vagrant visiting the site and remaining undetected.

The ongoing observations of spotless crakes confirm the presence of a resident population. Marsh crake also appear to be resident, but likely only a single individual or pair. Both are classed as ‘at risk, declining’, confirming the importance of the wetlands and waterbodies at Tiromoana Bush CMA. After a dip in counts last year, mean crake counts this year are higher than in 2018 and 2019, allaying concerns of a decline. Overall, changes in the three years were not significant.

Variability in counts could be related to population fluctuations or to changes in call rates or detectability. In several American rail and crake species, vocalization probability was positively correlated with density (Conway & Gibbs 2011). Crakes are known to be surprisingly mobile over large distances, so may move between wetlands at Tiromoana and Amberley. But breeding birds are resident in their territory in October, as breeding begins in August or September (Readers Digest Services 1985). Numbers of crakes counted at Tiromoana fluctuated between four and seven on consecutive days, implying some variation in call rates. Ambient temperature, wind speed, cloud cover, and moon phase affected detection probability in some, but not all, studies of (Conway & Gibbs 2011). An analysis of these environmental variables on call counts at Tiromoana will be conducted in future, when more data has been collected.

Power to detect a significant difference between individual years is poor for crakes. When the next survey period is complete, comparing survey periods by combining the three years would increase sample size and will increase power to detect a significant difference, as long as variance between years is not high.

A more reliable way to increase power to detect moderate changes in crake population size could be through acoustic monitoring. Advantages include the ability to increase sample size to 60+, ability to sample during the most active time of day or night to increase detections and power, and the ability to sample multiple species simultaneously and increase probability of detecting any rare or vagrant species such as bittern. A disadvantage is the additional cost of gear required, processing time and an extra trip to Tiromoana to deploy recorders. It would also not be possible to compare results to those obtained in 2017-19, hence a before/after assessment of the effects of predator control is not possible. Passive monitoring also appears to have a lower response rate for crakes at Kate valley (Buckingham et al. 2018, so it is likely several months of recording would be necessary, aiming for 2-3 recorders). Ideally wetland acoustic monitoring would be carried out in conjunction with present call playback monitoring if funding allowed.

Predator control and an increase in the area of wetland vegetation around waterbodies at Tiromoana is likely to increase the crake population present, and to provide habitat for other species such as bittern. Bittern are 'Nationally critical' and seasonally move around a network of wetlands, favouring raupo-fringed lakes, spring-fed creeks with cover and areas of rank-grass along the edges of wetlands and drains (Williams 2013).

Spotless crake, marsh crakes are known to use Raupo and *Carex secta* for habitat and nesting (Readers Digest services 1985). At Tiromoana, suitable raupo and *Carex secta* habitat covers 2.6 ha (1.48 ha of Kate pond, 0.95 ha of redwood swamp and pond, 0.15 ha of the water supply pond, and 0.02 ha of Ella pond) (analysis via GoogleEarth). At Aorangi in 1980, the smallest spotless crake territory was 45 x 50 metres, or approximately 4 pairs per ha (Onley 1982). At this density there is sufficient habitat for a maximum of 10 pairs of spotless crakes at Tiromoana. At a minimum of seven birds counted in any one night, the population could be as low as one third of capacity, or could be close to capacity if all birds did not respond and habitat is not ideal. The area of Tiromoana wetland covered in raupo is growing slowly, and has the potential to grow by up to 1 ha in the waterbodies. The area of Raupo and *Carex secta* could also grow by several hectares in wetlands presently dominated by pasture, but regeneration would occur very slowly without restoration planting and release from grasses. Ella pond in particular has potential for a large increase in the area of raupo and *Carex secta*, which would naturally spread once 'seed islands' are established. Presently, the area of raupo is too small to support crakes.

Mammalian pests

Incidental observations of pigs in 2019 included 8 adults and 6+ piglets (Appendix B). This compares to only three observations in 2018. Although these observations are anecdotal, they are based on constant effort (km covered and time spent in the CMA), so are strongly indicative of an increase in pig numbers. The number of pigs and piglets, and the extensive grubbing observed, suggest there is a significant and actively breeding population of pigs. It is clear that regeneration is being damaged and sediment lost to waterways, as heaviest pugging was observed in gully bottoms and valley floors. Ground nesting waterfowl and crakes may be at risk of predation, as pigs were heard, or grubbing observed, around the edges of all three waterbodies.

Deer and goats are not abundant, but goats are present and deer are likely to be present. Monitoring and control of ungulates, and surveillance and maintenance of the fence are important, as steep hills with loess soil are prone to slipping and erosion.

RECOMMENDATIONS

Pest control

- Increase efforts to monitor and control pigs, particularly around the waterbodies and valley floor.
- Repair the observed gap in the deer fence to exclude feral animals. Consider regular surveillance of the parts of the fence at risk from slips and fallen trees.
- Ensure good coverage of mammalian predator control at transects 6, 7 and 8, where the greatest declines in bird counts occurred, and around the waterbodies and wetlands, where 'at risk' crakes and 'threatened' grey duck occur.
- Use best practice predator control, including rodents as well as mustelids, cats and possums, particularly in areas with sensitive species.

Revegetation

- Planting of small 'seed islands' of raupo and *Carex secta* at the margins of Ella pond would be a cost effective way to establish more habitat for spotless crake, marsh crake bittern and fernbird.

Bird Survey and analysis

- Continue wetland bird playback surveys, and consider adding acoustic monitoring at three sites from August to increase sample size.
- To increase statistical power, survey waterfowl whenever passing by one of the waterbodies, aiming for at least 5 replicates per year.
- Repeat an analysis of the effect of temperature, wind, cloud, rain and noise on five-minute bird counts when more data is collected after the next set of monitoring years. Also carry out this analysis for waterfowl and crakes when more data is collected.
- Use a mixed model analysis for gregarious waterfowl birds in future when more data is collected.
- For waterfowl and wetland birds, statistically compare survey periods (blocks of years) rather than individual years once a second period of monitoring is complete.
- Begin the next period of bird monitoring between 2022 and 2024 and continue for 3-5 years to determine whether predator control is effective in restoring native birds.
- To effectively monitor wetland birds, waterfowl and rarer forest birds, consider diverting resources from reporting to increasing survey effort. Reporting and analyses can be completed every second year surveyed, or to the end of each 3-5 year period of monitoring. Basic tables of results can be provided in the intervening years.

Many recommendations from 2017 and 2018 reports still apply but are not repeated here.

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APPENDIX A

Annotated bird list grouped according to habitat (2005-2018)

Table A1. Forest and scrub birds, including some species that are also found in open habitat. (NT= Not Threatened). Species in bold type were found in the CMA in 2019, in counts or incidentally.

Common Name	Latin Name	Gen. Status	Threat status	Abundance
Kereru	*Hemiphaga novaeseelandiae*	Endemic	NT	Occasional 2019, Rare in 2017-18. One record 2005-2009
Shining cuckoo	*Chrysococcyx lucidus*	Native	NT	Occasional 2005-2018, frequent 2019
Kingfisher	*Todiramphus sanctus vagans*	Native	NT	Occasional 2005-2019
Grey warbler	*Gerygone igata*	Endemic	NT	Common all years
Brown creeper	*Mohoua novaeseelandiae*	Endemic	NT	one record in 2009
South Island fantail	*Rhipidura fuliginosa*	Native	NT	Frequent all years
South Island tomtit	*Petroica macrocephala*	Endemic	NT	Rare records (one individual in 2007, 2017 and 2018, two incidental in 2019)
Silvereye	*Zosterops lateralis*	Native	NT	Common all years
Bellbird	*Anthornis melanura*	Endemic	NT	Common all years

Table A2. Birds found mainly in open or partly scrubby areas.

Common Name	Latin Name	Gen. Status	Threat status	Abundance
Australasian harrier	*Circus approximans*	Native	NT	Frequent
Skylark	*Alauda arvensis*	Introduced	NT	Common
Blackbird	*Turdus merula*	Introduced	NT	Common
Song thrush	*Turdus philomelos*	Introduced	NT	Common
Yellowhammer	*Emberiza citrinella*	Introduced	NT	Common
Goldfinch	*Carduelis*	Introduced	NT	Common
Redpoll	*Carduelis flammea*	Introduced	NT	Common
Starling	*Sturnus vulgaris*	Introduced	NT	Local, infrequent

Australian magpie	*Gymnorhina tibicen*	Introduced	NT	Occasional - Frequent
Spur-winged plover	*Vanellus miles navaehollandiae*	Native	NT	Occasional, not in 2018, 2019
California quail	*Callipepla californica*	Introduced	NT	Occasional - locally frequent
Dunnock	*Prunella modularis*	Introduced	NT	Common all years
Chaffinch	*Fringilla coelebs*	Introduced	NT	Common all years

Table A3. Indigenous birds found in open valley near creeks and ponds.

Common Name	Latin Name	Gen. Status	Threat status	Abundance
Black shag	*Phalacrocorax carbo navaehollandiae*	Native	At risk: Naturally Uncommon	One record, 2007
Pied shag	*Phalacrocorax varius*	Native	At risk: recovering	One record, 2018
White-faced heron	*Ardea novaehollandiae*	Native	NT	Occasional, not 2019
Southern black-backed gull	*Larus dominicanus*	Native	NT	Occasional
Welcome swallow	*Hirundo tahitica neoxena*	Native	NT	Frequent

Table A4. Waterfowl and wetland species

Common Name	Latin Name	Gen. Status	Threat status	Abundance, notes
Black swan	*Cygnus atratus*	Introduced/self-introduced	NT	1-2 pairs every year, Breeding
Canada goose	*Branta canadensis*	Introduced	NT	Common, breeding
Paradise shelduck	*Tadorna variegata*	Endemic	NT	Common, breeding
Mallard	*Anas platyrhynchos*	Introduced	NT	Common, breeding
Grey duck (likely with some	*Anas superciliosa (x Anas platyrhynchos)*	Endemic x Introduced		Occasional in 2017 and 2018, breeding

mallard hybridization)				
Grey teal	*Anas gracilis*	Native	NT	Variably occasional-common. None in 2018
New Zealand scaup	*Aythya novaeseelandiae*	Endemic	NT	Common each year
Australasian Shoveler	*Anas rhynchotis*	Native	NT	Common
Pied stilt	*Himantopus leucocephalus*	Native	NT	A few each year. None in 2018, 2019
Spotless crake	*Porzana t. tabuensis*	Native	At risk: declining	Eight responded to playback in 2017, four in 2018
Marsh crake	*Porzana pusilla affinis*	Native	At risk: declining	One heard in 2018 and 2019, and possibly one or two in 2017

Table A5. Unconfirmed species.

Common Name	Latin Name	Gen. Status	Threat status	Abundance, notes
Grey duck	*Anas superciliosa*	Endemic	Nationally Critical	Possibly some pure grey duck each year, but genetics required to confirm
Tui	*Prosthemadera n.novaeseelandiae*	Endemic	NT	One presumed heard at Transect 8, in 2005

APPENDIX B

Incidental observations

Table B1. Incidental bird observations at Tiromoana Bush CMA in 2019

Species	Date	Time	NZTM E	NZTM N	Number
Tomtit	19-Oct-19	20:15	1589083	5228789	2
Kereru	21-Oct-19	09:38	1587430	5228237	1

Table B2. Incidental mammalian pest observations at Tiromoana Bush CMA in 2019

Species	Date	Time	Location	Number
Pig	17-Oct-19	11:50	kate pond view point near 5MBC station 5c	1 adult, 2 piglets
Pig	19-Oct-19	20:35	kate pond wetland count station W12	1 adult
Pig	19-Oct-19	17:35	5MBC station 1b	1 adult
Pig	19-Oct-19	20:20	kate pond wetland count station W12	1 adult
Pig	21-Oct-19	14:12	near 5MBC station 1b	1 adult, 3 piglets
Pig	25-Oct-19		near 5MBC station 12b	2 adults
Pig	26-Oct-19		near 5MBC station 9a	1 adult, 1+ piglets
Goat	16-Oct-19		near 5MBC station 9c	2