Monitoring Birds at Tiromoana Bush Conservation Management Area, Canterbury, 2017

Rhys Buckingham, Brian Lloyd & Jeroen Lurling

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Tiromoana Bush Conservation Management Area showing the Kate Valley wetlands surrounded by patches of generating mixed broadleaved forest, plantings and taller kanuka dominated forest patches. (Photo: Jeroen Lurling).

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EXECUTIVE SUMMARY

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. The initial phase of the bird monitoring programme was carried out with surveys in October each year during the period 2005–2009 and the second phase began in October 2017. 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.

Field methods and analysis

Modified five-minute bird counts (after Dawson & Bull 1975 and Moffat & Minot 1994) were used to monitor forest birds. Analyses of the count data were undertaken to: evaluate bird population trends between 2005 and 2017; assess the effectiveness of the distance sampling method used to augment five minute bird counts; and evaluate differences between the performance of two observers (the original observer and their replacement) to ensure that the results from previous and future monitoring will be comparable.

Acoustic recorders were used to record bird calls during a sub-sample of the five-minute bird counts. Programmable acoustic recorders were also used at selected bird count transects to record several hours of diurnal and nocturnal birdsong each night during the 2017 monitoring session. The recording are backed up and stored for possible later use as an additional monitoring tool.

Waterfowl were surveyed separately, with visual counts at open water areas within the CMA. For the more elusive wetland birds, call playback surveys were conducted.

Results

Thirty-two bird species (18 indigenous and 14 introduced) were confirmed as present in the CMA during the October 2017 survey. Two species encountered during previous surveys (kingfisher and brown creeper) were not encountered in 2017, but an additional species (spotless crake) was found for the first time. Threatened species present in the CMA include black shag (At Risk: Naturally Uncommon), and spotless crake (At Risk: Declining). Grey duck (Nationally Critical) were also tentatively identified as being present, but there is some uncertainty because grey duck-mallard hybrids are difficult to distinguish from pure grey duck. Rare forest birds encountered during 2017 include tomtit (one individual only) and kereru. Kingfisher and brown creeper were not recorded in 2017.

A secretive and previously undetected species, spotless crake, was detected using call playback. This is a new distribution record for spotless crake, with few other records in Canterbury or the South Island (O'Donnell 1994; Robertson et al. 2007). The same waterfowl species were recorded occupying open water areas during the 2017 as previously. The most common species were: black swan, Canada goose, Australasian shoveler and New Zealand scaup.

Although there have been minor fluctuations in the forest bird species composition during the period 2005 to 2017, the various diversity indices showed relatively little variation between years. Species richness showed little change throughout the thirteen-year period. Bellbird, grey warbler, silvereye and fantail continue to be the most abundant indigenous bird species recorded during five-minute counts. Although few kereru were recorded on counts, the number present in the area was higher during the 2017 monitoring session than previously.

The mean count for all species declined by 40% between the 2005 and 2017 surveys, with a 27% decline ($p<0.001$) in the mean count of native species and a 50% decline ($p<0.001$) in the mean count of exotic species. The decline in native species was driven by a decline in the numbers of bellbird, the single most abundant species.

Differences between results obtained from the two observers in 2017 were examined in detail. Although the two observers generally recorded the same species during each count, there were significant differences between the numbers of individuals recorded by the two observers for several species (silvereye, grey warbler greenfinch and dunnock). There were also marked differences in the two observer's ability to estimate distances. The instability of results from distance sampling analyses is assumed to be due mainly to: 1) difference in the hearing abilities of the two observers; 2) insufficient training in estimating distances to birds; and 3) the difficulties of estimating horizontal distances to birds that are heard but not seen.

There was good correlation (correlation coefficients 0.84 & 0.80; p-values <0.001) between mean counts and density estimates from distance sampling for most the eleven common species observed in 2017. However, there were serious inconsistencies for two species: grey warbler and silvereye.

Discussion

The similarities in bird species compositions and diversity between the current 2017 survey and earlier surveys are not surprising given that there have not been dramatic changes in the habitat since 2005. Removal of stock and exclusion of deer have resulted in notable understory regrowth and improvements in the growth and condition of indigenous plantings. However, the plantings are young and the forest patches are still discrete, with similar structure and composition to twelve years ago. Thus, there has been little change in the quality of bird habitat since 2005.

The significant decline in bird numbers, especially bellbirds and finches, between 2005 and 2017 cannot be easily explained. Further monitoring will be required to see whether the observed trend is part of a continuing decline or merely a cyclic fluctuation in numbers. The overall species decline is largely driven by a decline in bellbirds, the commonest species. If the decline in bird counts reflects an actual decline in population densities as seems likely, introduced mammalian predators are the most probable causal agents for this decline. Other variables, such as weather conditions, are not consistent with the decline in bird counts between 2005 and 2017.

The scarcity, or absence, of many indigenous forest bird species in the CMA and low comparative species diversity, is probably a consequence of the combined effects of forest fragmentation, small patch size, forest modification by browsing mammals, and high numbers of mammalian predators. It seems likely that indigenous bird species numbers and diversity will increase as natural regeneration takes its course and the forest patches are extended and connected by further planting. However, a positive outcome for birds will only be achieved through robust control of mammalian predators and competitors.

The presence of a population of spotless crake is of national significance because it is a threatened species not previously recorded from the area (Robertson et al. 2017). Spotless crake have been recorded in Canterbury previously, but records are scant in the South Island (O'Donnell 1994; Robertson et al. 2007). Several ducks observed in 2017 had features more consistent with grey duck than mallard. However, grey duck and mallard hybridise, and it is difficult to distinguish hybrids from pure grey ducks.

Increasing the area of wetland habitat in the CMA is important for populations of species currently occupying them, and to provide colonisation opportunities for other species such as bittern. Wetland habitat has been reduced by over 90% nationwide and most wetland bird species are listed as threatened or at-risk, including bittern and grey duck, which are both listed as Nationally Critical. Kate Valley forms a key component of a network of wetlands along the north Canterbury coast, and if restored further, has potential as focal habitat for threatened and at-risk wetland birds. Restoration would bolster its value as a key stepping stone between the coastal dune swale and estuary wetlands to the south, and Mata Kopae/St Anne's Lagoon and the Kaikoura wetlands to the north.

Recommendations

- Best practice predator control management should be implemented to arrest decline of forest bird numbers within the CMA. Regular monitoring of mammalian predators and browsers numbers should also be carried out.
- If best practice predator control is undertaken, the area should become suitable for reintroductions of species such as fernbird and robin. Populations of tomtit and brown creeper could also be enhanced by reintroductions.
- The former valley floor wetlands should be restored to their former extent to increase the area of habitat for wetland birds. Extending shrublands and *Carex* sedgelands will provide suitable habitat for fernbird, while increasing the area of shallow water edges with raupo and *Carex secta* will provide extra crake and bittern habitat.
- Playback surveys for threatened and at-risk wetland birds (including spotless crake, marsh crake, bittern and fernbird) should be continued and standardised.

- Detailed morphological assessments of 'grey/mallard' ducks should be carried out during future wetland surveys to determine whether there are purebred grey ducks present.
- Increasing the use of acoustic recorders for monitoring forest birds should be considered, as this is likely to become a standard method to monitor NZ's forest birds in the future.
- There should be ongoing scrutiny of density estimates obtained from distance sampling analyses to improve the quality of the data collected and ensure that the method is effective. Future distance counts should entail daily calibration of distance estimates, using a rangefinder.

Conclusion

The bird monitoring carried out within the CMA provides baseline data for evaluating long-term bird population trends in the area. However, some caution is required when interpreting trends because counts and density estimates can be affected by a number of factors such as observers' performance, variation in the timing of breeding seasons, weather conditions, and predator abundance.

A more focused survey of wetland species during 2017 resulted in at least one new species being recorded: the spotless crake, listed by DOC as 'At Risk: Declining' (Robertson et al. 2017). Further surveys are required to confirm whether marsh crake are present and whether ducks seen in the area are critically threatened grey duck or almost indistinguishable mallard-grey duck hybrids.

Occasional observation of species such as kereru, tomtit and brown creeper in the area suggests that these and other species will colonize the area successfully once the quality and extent of forest and scrub habitat improves. However, the significant decline in bird numbers, especially bellbird, between 2005 and 2017 cannot be easily explained. Further monitoring will be required to see whether the observed trend is part of a continuing decline or merely a cyclic fluctuation in numbers. The overall species decline is largely driven by counts of bellbird, the commonest species. If the decline in counts reflects an actual decline in population densities as the results indicate, introduced mammalian predators are likely to be the key cause. Predator control would be essential before considering relocations of birds such as tomtit, robin or fernbird to the CMA. Maintaining wetland habitat is crucial for the protection of species currently occupying them. Restoration of former wetland areas would offer new colonisation opportunities for endangered species such as bittern.

BACKGROUND

Transwaste Canterbury Ltd 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, and establishment of a deer fence exclusion area (Norton 2012).

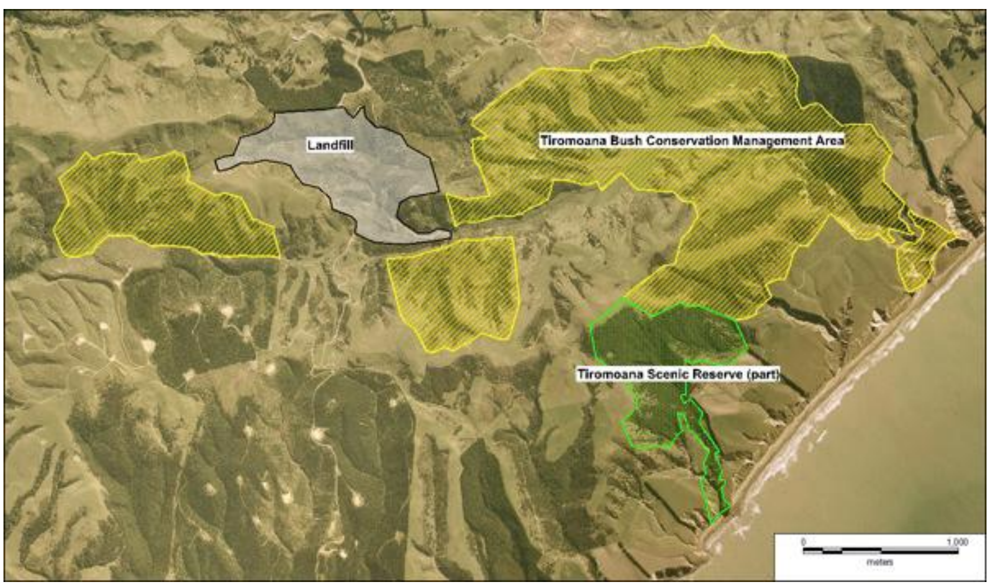


Figure 1. Tiromoana Bush Conservation Area (yellow hatched) in relation to the Canterbury Regional Landfill and adjacent public conservation land (Norton 2012).

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. The second series of monitoring began in October 2017 and the results of this are presented in this report. While the first series of monitoring involved a single observer (Rhys Buckingham), the current monitoring involved an additional observer (Jeroen Lurling) who will carry out future monitoring alone. To facilitate comparison between the results from monitoring undertaken during the 2005–2009 period and future monitoring, the two observers' performances during the 2017 surveys were compared.

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). Bird species not typically associated with forest or scrub 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.

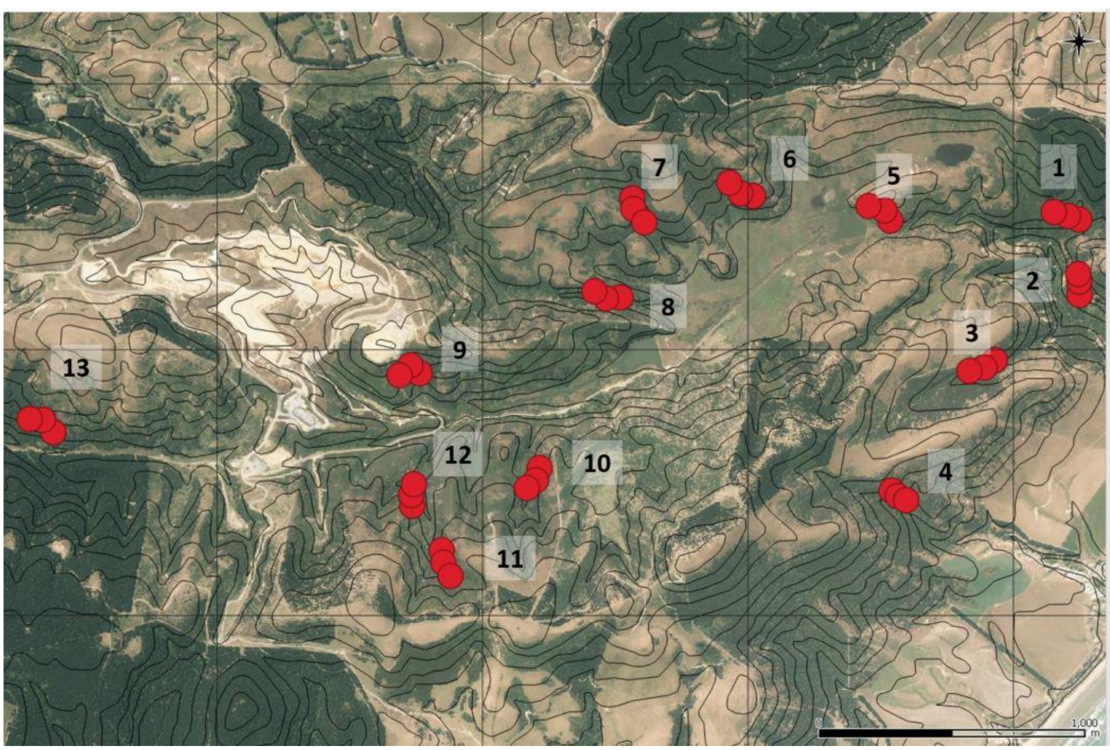


Figure 2. Bird count transects at Tiromoana Bush Conservation Area.

Surveys were undertaken during October in each of the six years 2005–2009 and 2017, with at least three replicate surveys each year. During each survey, counts were undertaken at 39 count sites, with three count sites spaced at *c*. 50 m intervals along each of thirteen transects (Figure 2). Right truncation at 200 m gives a survey area of 12.6 ha around each count site and, with 33 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 distance estimates were recorded for all species.

Surveys were only undertaken between 08:00 hrs and 15:30 hrs NZDT during suitable weather condition: without strong wind or heavy rain. 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).

During the period 2005 to 2009, all surveys were undertaken by a single observer (Rhys Buckingham, hereafter Observer A), but during 2017 surveys were undertaken by Observer A and a second observer (Jeroen Lurling, hereafter Observer B) working together recording simultaneous, but independent, counts at each site. Because Observer B will replace Observer A during future monitoring, observer count ability was compared to enable sampling continuity.

Acoustic monitoring

Acoustic monitoring was carried out simultaneously with five-minute bird counts during relatively calm and dry weather on at least one replicate count on all of the transects. For this purpose a Sony Hi Minidisc™ Linear PCM recorder (Sony MZ-R909) and Vizivox Hammerhead™ stereo omnidirectional microphone was deployed to record bird calls within an approximate 100 m radius during the five-minute count. Sony Sonic Stage™ software was used to analyse recordings converted to a WAV file format.

Five Wildlife Acoustics SongMeter2™ professional programmable recorders were also deployed on five transects, selected to represent all vegetation communities within the CMA. The recorders were placed at the centre (Count 2) of transects numbers: 1, 3, 5, 8 & 10 (Figure 2). The recorders were programmed to record daily between 6 am and 12 noon (diurnal) and 9 pm and 1 am (nocturnal). Recordings are backed up and stored until an appropriate programme to analyse the calls of New Zealand forest birds is available.

Acoustic recorders were also set up at the playback survey points for wetland birds, moving them between points on consecutive nights to achieve coverage of all potential habitats. The Hi Minidisc recorder was used to obtain high quality recordings of local dialects.

Wetland Birds

As in previous years, waterfowl on the open water dams and ponds were surveyed using visual counts with binoculars from vantage points. In 2017, a more methodical approach was adopted to establish a standard survey method for future comparisons between years. Survey stations were established at high points with good overviews, and counts were repeated at each survey station on three separate days.

The more elusive 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 on three separate evenings. Playback calls were downloaded from the *nzbirdsonline* website and played using a bluetooth speaker and smartphone. Occasionally the smartphone was used without the separate speaker, when observers split up. Calls were played at a number of points 50–100 m apart along transects through all wetland areas. Approximately one minute of each species call was played, and then repeated. On the last survey day, calls were played at the selected survey points to ensure full coverage of all suitable habitat and to standardise effort between years. Observers generally held the speaker, but occasionally the second observer stood some distance away and on one occasion heard a call during playback. It is recommended in future surveys the surveyor stand at least 10 m from the speaker. This first year could be regarded as a pilot study, since survey techniques were not fully standardised. Both the Sony Hi Minidisc™ and SongMeter™ recorders were used to record calls of crake and other crepuscular and nocturnal bird species.

Statistical Analysis

Statistical analysis were undertaken to: evaluate forest and scrub bird population trends between 2005 and 2017; evaluate differences between the two observers' counts that might affect continuity of data collection; and assess the effectiveness of the distance sampling method used to augment five-minute bird counts. No statistical analyses were carried out on wetland birds and waterfowl counts, because 2017 was the first year when playback surveys and standardised waterfowl visual survey were undertaken. Similarly, statistical analysis was not performed on data from the acoustic recorders.

Generalised Linear Mixed-effects Modeling

Because the five-minute 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 and negative binomial error distributions and log-link function were used to compare total counts between years and observers, and investigate the influence of weather conditions. GLMMs were implemented using the R-functions *glmer* and *glmer.nb* for Poisson and negative binomial error distributions respectively. Individual count-site identity was used as a grouping factor (i.e. random effect) for comparison between years, while individual count identity was used as a grouping factor for comparison between the two observers. For GLMM analyses, year values and observer identity were converted to unordered factors, while environmental condition scores were converted to ordered factors. Best models were selected using R-functions *anova* and *drop1* for model comparison using Chi-square tests and the AIC criterion respectively (Crawley 2002; Venables and Ripley 2002). Although GLMMs were undertaken with both Poisson and negative binomial error distributions, results using the two error distributions were almost identical, consequently only results from GLMM's with Poisson error distributions are reported.

Distance Sampling Analyses

Bird densities were estimated using distance sampling methods (Buckland et al., 2004 & 2015) implemented in the R-package *Distance* (Miller 2017; Miller et al. 2016). The R-function *ds* was used to fit both half-normal (*N*) and hazard-rate (*R*) 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*.

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 original 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.

Investigating Trends in Species Composition

Functions in the R-library for descriptive community ecology *vegan* (Oksanen et al., 2018) were used to investigate trends in the species compositions of the five-minute bird counts. Diversity and dissimilarity indices were computed using the R-functions *diversity* and *vegdist*. Principal Components Analyses (PCA) were undertaken using the function *rda*.

RESULTS

General Results

Thirty-two bird species (18 indigenous and 14 introduced) were recorded in the CMA and environs during October 2017 (Appendix). Two species found on previous surveys (kingfisher and brown creeper) were not encountered during 2017, but an additional species (spotless crake) was found for the first time using call playback. Threatened species include black shag (At Risk: Naturally Uncommon) and spotless crake (At Risk: Declining). Grey duck (Nationally Critical) were also tentatively identified, but it is difficult to distinguish purebred grey ducks from grey duck/mallard hybrids. The rarest bird species encountered during five-minute counts in 2017 was tomtit, with only one individual recorded during two replicate counts on Transect 13 in 2017. (There is only one previous record of tomtit: on Transect 11 in 2007.)

Harriers were frequently heard flying above the canopy. Although kereru were rarely recorded during counts, the number of overall encounters was higher than during previous monitoring years. The assemblage of bird species on the various ponds and wetland in 2017 was similar to previous years. Conspicuous species included: black swan, Canada goose, paradise shelduck, Australasian shoveler, grey teal, New Zealand scaup and pied stilt. The specialised playback surveys confirmed the presence of one species of crake (spotless crake) in the raupo wetland area of Kate Valley. These birds were vocally active during the late afternoon and evening. This is a new distribution record for spotless crake, but they are known to be present elsewhere in Canterbury (O'Donnell 1994; Robertson et al. 2007).

Statistical Analyses of Five-minute Bird Counts

Seventeen forest bird species were observed on bird counts undertaken at the CMA during the period 2005 to 2017 (Table 1)[1]. Sixteen of the seventeen species were encountered during the 2005 to 2009 surveys (Table 2); with kingfisher only encountered during the 2005 to 2009 surveys, and kereru only observed during the 2017 survey. For analyses, species were allocated to two groups: *Common* and *Rare*. *Common* species were those with mean counts ≥ 0.1 observations per five-minute count, while *Rare* species had mean counts < 0.1 observations per five-minute count. There were eleven common species and six rare species. The common species included four native species and seven introduced species. The rare species included four native and two introduced species.

Numbers of Species 2005 to 2017

The number of species observed by Observer A during each of the six surveys was relatively stable varying between fourteen and sixteen (Tables 3 & 4). The numbers of native species ranged from six to seven, with seven native species observed during surveys in 2007 and 2017, and six during each of the other four surveys. Eight exotic species were observed during survey in 2005 and nine during each of the other five surveys, 2006 to 2017. Five native species were observed during all years (Tables 2 and 3): shining cuckoo and the four common native species (i.e. bellbird, fantail, silvereye and grey warbler). Kingfisher were observed every year from 2005 to 2009, but not in 2017. Kereru were only observed (on counts) in 2017 and tomtit were only observed in 2007 and 2017. Quail were the only one of the nine exotic species not observed in 2005.

Heard versus Seen

Out of a total of 9,750 observations by the two observers, 96.7% were acoustic and only 3.3% were visual. The proportions of the two types of observations varied significantly ($p<0.001$)

[1] Note that harrier, magpie and yellowhammer were excluded from analysis these two species are not usually associated with forest patches.

between species, ranging from 50% for kereru, to 100% for kingfisher, shining cuckoo and quail (Table 1).

Table 1. List of species observed during Tiromoana bird surveys during the period 2005 to 2017, both observers. Native species are denoted by upper-case lettering.

Species	Total Observations	Proportion First Heard	*Mean Count (Observations per 5-min. count)*
a) *Common*			
BELLBIRD	2,397	*92.4%*	*2.80*
FANTAIL	205	*91.7%*	*0.24*
SILVEREYE	769	*95.6%*	*0.90*
WARBLER	1,010	*98.0%*	*1.18*
Blackbird	512	*97.7%*	*0.60*
Song thrush	402	*99.5%*	*0.47*
Chaffinch	1,615	*98.9%*	*1.89*
Dunnock	542	*97.8%*	*0.63*
Goldfinch	584	*98.5%*	*0.68*
Greenfinch	699	*99.4%*	*0.82*
Redpoll	864	*99.0%*	*1.01*
b) *Rare*			
KERERU	2	*50.0%*	*0.00*
KINGFISHER	24	*100%*	*0.03*
SHINING CUCKOO	55	*100%*	*0.06*
TOMTIT	8	*87.5%*	*0.01*
Quail	32	*100%*	*0.04*
Starling	30	*90.0%*	*0.04*
Total:	9,750	*96.7%*	*11.40*

Comparing five-minute Bird Counts During the Period 2005 to 2017

The mean of combined counts for all species during the six surveys undertaken by Observer A declined from 14.3 (CI95%: 13.7–15.0) observations per five-minute count in 2005 to 8.6 (CI95%: 7.9–9.3) observations per five-minute count in 2017 (Table 2 & 3,), a decline of 40%.

There were minor fluctuations in the species compositions of observations during the period 2005 to 2017 (Table 3 and 4; Figure 3). Typically mean counts (i.e. mean number of observations per five-minute count) of individual species (Tables 2 and 3; and Figure 3) varied more widely between years than the mean counts of all species combined, with the lowest annual mean counts for individual species ranging from 39.7% to 100% lower than the highest count.

GLMM of counts by year

In GLMM's using the model: *Total Count ~ Year+|SiteID*, with observations from all surveys undertaken by Observer A during the period 2005 to 2017, year was significant (p<0.001) for all species combined. In GLMM's of the effect of year on individual species' counts during the period 2005 to 2017, year was significant (p<0.001) for all common species.

Significance levels for the effect of year in individual species counts during the period 2005 to 2009 and for comparisons of counts in 2009 and 2017 are presented for common native species in Figure 4. Between-year contrasts between species counts for surveys during the period 2005 and 2009 aren't presented, but can generally be inferred from the amount of overlap between 95% confidence intervals around the mean counts in Figure 4. If there is no vertical overlap between confidence intervals, the means will be significantly different. There were insufficient observations for successful GLMM analyses of individual rare species.

Trends in species counts

There was a 27% decline in the mean count (p<0.001) of all native species combined between 2005 and 2017 surveys. The trend wasn't consistent throughout the period (Figure 5 and Table 4). Although there were declines of 5% to 19 % between most consecutive surveys there was a 27% increase (p<0.001) between the 2007 and 2008 surveys. The overall trend for the combined count of native bird species is driven by, and closely mirrors, the trend for bellbird, the most abundant species during the surveys (Figure 4 and Tables 2 & 3). Trends for the other three common native species (fantail, silvereye and grey warbler) are different to the bellbird's trend and don't show a consistent pattern (Figure 4).

The decline in exotic species between 2005 and 2017 was larger than the decline in native species, with a 50% decline in the mean count (p<0.001) of all exotic species combined between 2005 and 2017 surveys. Between 2005 and 2008, trends in the pooled mean counts of native and exotic species (Table 4 and Figure 5) were closely aligned. Both groups experienced similar declines between 2005 and 2007, followed by similar increases between 2007 and 2008. Although mean counts of both native and exotic species declined after 2008, declines in the exotic species were considerably greater than declines in the native species: 28% and 30% compared to 5% and 13%. The 5% decline in native species between 2008 and 2009 was not significant, but all other changes in pooled mean counts between consecutive surveys were significant for both groups of species. Declines in the exotic species after 2008 were restricted to the four finches (chaffinch, goldfinch, greenfinch & redpoll) and dunnock (Table 2 & 3; Figure 3). Species usually associated with open country.

Table 2. Summary statistics for the 2005 to 2009 surveys for all species separately.

	Mean N. of observations per five-minute count *(CI95%)*									
Year:	2005		2006		2007		2008		2009	
N. of counts:	117		120		123		123		126	
N. of species:	15		16		16		16		16	
a) <u>Common</u>										
BELLBIRD	3.68	*(3.3–4.0)*	2.85	*(2.5–3.2)*	2.20	*(1.9–2.5)*	3.47	*(3.1–3.9)*	2.93	*(2.6–3.3)*
FANTAIL	0.45	*(0.3–0.6)*	0.27	*(0.2–0.4)*	0.16	*(0.1–0.2)*	0.07	*(0.0–0.1)*	0.13	*(0.1–0.2)*
SILVEREYE	0.85	*(0.6–1.1)*	0.63	*(0.5–0.8)*	0.63	*(0.4–0.8)*	0.66	*(0.5–0.8)*	0.60	*(0.4–0.8)*
WARBLER	1.03	*(0.9–1.2)*	1.37	*(1.2–1.6)*	1.11	*(0.9–1.3)*	1.11	*(0.9–1.3)*	1.44	*(1.3–1.6)*
Blackbird	1.26	*(1.1–1.5)*	0.54	*(0.4–0.7)*	0.36	*(0.2–0.5)*	0.24	*(0.2–0.3)*	0.33	*(0.2–0.4)*
Song thrush	0.72	*(0.6–0.9)*	0.62	*(0.5–0.8)*	0.45	*(0.3–0.6)*	0.20	*(0.1–0.3)*	0.33	*(0.2–0.4)*
Chaffinch	2.09	*(1.8–2.3)*	2.06	*(1.8–2.3)*	2.33	*(2.1–2.6)*	2.50	*(2.3–2.7)*	1.78	*(1.5–2.0)*
Goldfinch	0.97	*(0.8–1.2)*	1.42	*(1.1–1.7)*	0.69	*(0.5–0.9)*	0.87	*(0.7–1.1)*	0.48	*(0.3–0.6)*
Greenfinch	1.34	*(1.1–1.6)*	0.83	*(0.6–1.1)*	0.59	*(0.4–0.8)*	1.20	*(1.0–1.5)*	0.94	*(0.7–1.2)*
Redpoll	1.25	*(1.0–1.5)*	0.78	*(0.6–1.0)*	0.55	*(0.4–0.7)*	1.85	*(1.5–2.2)*	1.32	*(1.1–1.6)*
Dunnock	0.52	*(0.4–0.7)*	0.70	*(0.6–0.8)*	0.89	*(0.7–1.0)*	1.22	*(1.0–1.4)*	0.61	*(0.5–0.8)*
Common Species:	14.2	*(13.6–14.8)*	12.2	*(11.4–12.9)*	10.0	*(9.2–10.7)*	13.4	*(12.8–14.0)*	10.9	*(10.3–11.5)*
b) <u>Rare</u>										
KERERU	0		0		0		0		0	
KINGFISHER	0.06	*(0.0–0.1)*	0.04	*(0.0–0.1)*	0.03	*(0.0–0.1)*	0.04	*(0.0–0.1)*	0.02	*(0.0–0.1)*
SH. CUCKOO	0.04	*(0.0–0.1)*	0.07	*(0.0–0.1)*	0.10	*(0.0–0.2)*	0.06	*(0.0–0.1)*	0.03	*(0.0–0.1)*
TOMTIT	0		0		0.01	*(0.0–0.0)*	0		0	
Quail	0		0.08	*(0.0–0.1)*	0.02	*(0.0–0.1)*	0.02	*(0.0–0.1)*	0.09	*(0.0–0.1)*
Starling	0.05	*(0.0–0.1)*	0.03	*(0.0–0.1)*	0.05	*(0.0–0.1)*	0.04	*(0.0–0.1)*	0.01	*(0.0–0.0)*
All Species:	14.3	*(13.7–15.0)*	12.4	*(11.6 – 13.1)*	10.2	*(9.4–10.9)*	13.6	*(13.0–14.2)*	11.0	*(10.4–11.7)*

Table 3. Comparisons of five-minute bird counts undertake by the two observers during 2017. The column % Diff. is the difference between the two mean counts expressed as the percentage of Observer A's mean count. Negative values (i.e. red font) indicate that estimates from Observer A are lower than those for Observer B. Significance levels (i.e. *p*-levels) are from GLMMs with Poisson error distributions.

Year: 2017 N of counts: 123						
	Observer A		Observer B		% Diff.	*p*-level
N. of Species:	18		18			
	Mean	*(CI95%)*	Mean	*(CI95%)*		
a) Common						
BELLBIRD	2.32	*(2.0–2.6)*	2.21	*(1.9–2.5)*	5%	*NS*
FANTAIL	0.22	*(0.1–0.3)*	0.38	*(0.3–0.5)*	-74%	*
SILVEREYE	1.00	*(0.8–1.2)*	1.90	*(1.6–2.2)*	-90%	***
WARBLER	0.87	*(0.7–1.0)*	1.28	*(1.1–1.4)*	-48%	**
Blackbird	0.80	*(0.6–1.0)*	0.69	*(0.6–0.8)*	14%	*NS*
Chaffinch	1.34	*(1.1–1.6)*	1.09	*(0.9–1.3)*	19%	**§**
Dunnock	0.15	*(0.1–0.2)*	0.33	*(0.2–0.4)*	-116%	**
Goldfinch	0.15	*(0.1–0.2)*	0.22	*(0.1–0.3)*	-42%	*NS*
Greenfinch	0.50	*(0.3–0.7)*	0.34	*(0.2–0.5)*	32%	*
Redpoll	0.60	*(0.5–0.7)*	0.72	*(0.5–0.9)*	-20%	*NS*
Song thrush	0.48	*(0.4–0.6)*	0.52	*(0.4–0.7)*	-8%	*NS*
Common Species:	8.4	*(7.8–9.1)*	9.7	*(9.1– 10.4)*	-15%	***
b) Rare						
KERERU	0.01	*(0.0–0.0)*	0.01	*(0.0–0.0)*	0%	
KINGFISHER	0		0			
SH. CUCKOO	0.07	*(0.0–0.1)*	0.09	*(0.0–0.1)*	-37%	
TOMTIT	0.02	*(0.0–0.0)*	0.04	*(0.0–0.1)*	-150%	
Quail	0.02	*(0.0–0.0)*	0.02	*(0.0–0.1)*	-50%	
Starling	0.04	*(0.0–0.1)*	0.03	*(0.0–0.1)*	20%	
All Species:	8.6	*(7.9–9.3)*	9.9	*(9.2 –10.6)*	-15%	***

NS ~p>0.1; **§** ~ p<0.1; * ~ p<0.05; ** ~p<0.01; *** ~p<0.001

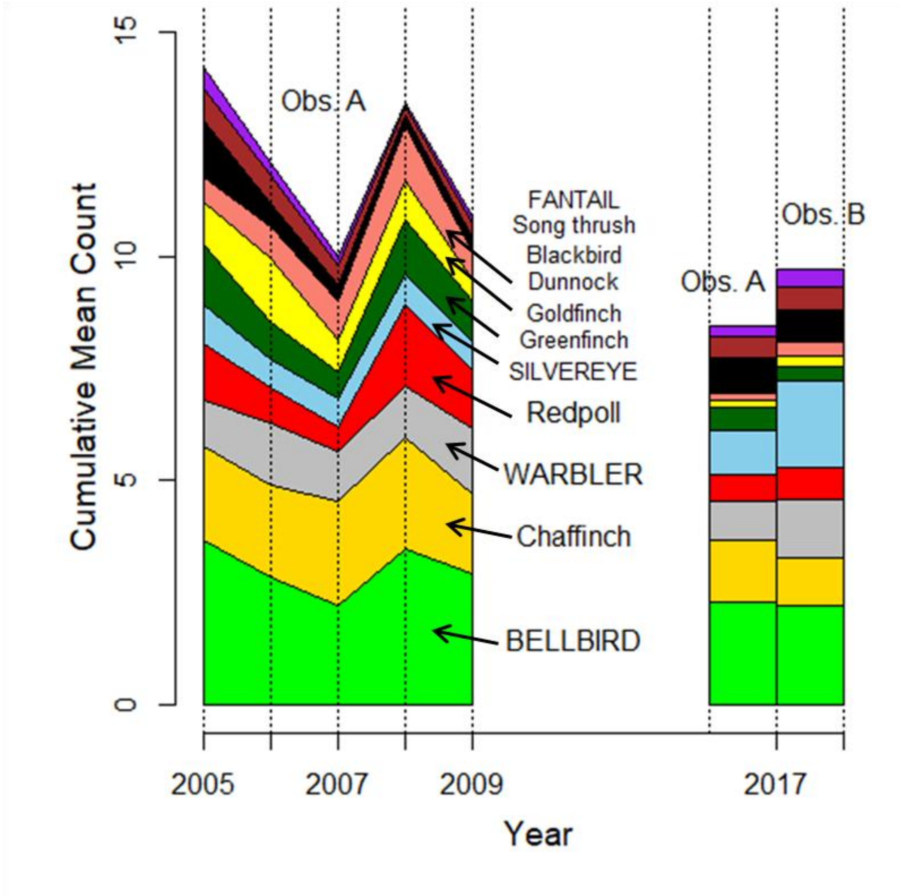


Figure 3. Changes in the species composition of counts by Observer A during the six annual surveys 2005–2009 and counts of both observers in 2017. Only the eleven common bird species are included in the plot.

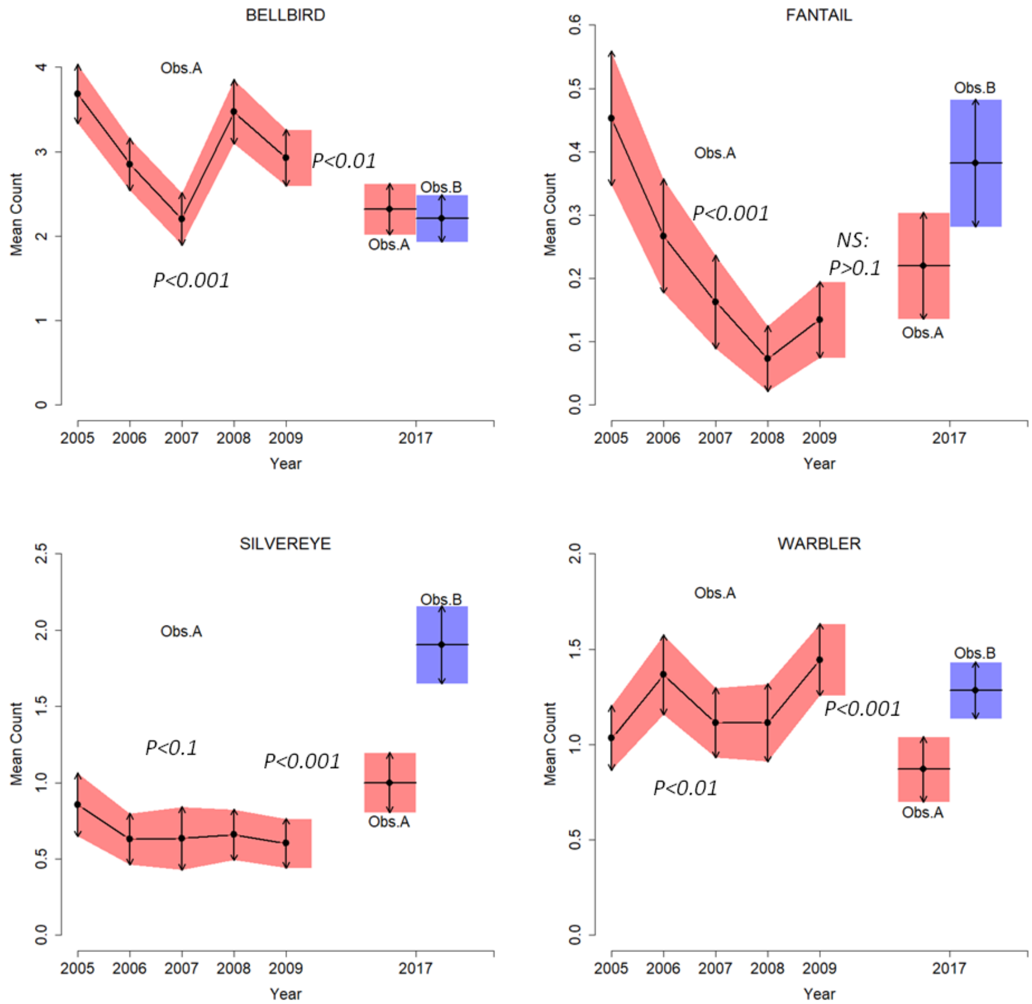


Figure 4. Plots of mean count by year for the four common native species during surveys 2005 to 2009 and 2017. Coloured areas and arrows show the 95% confidence intervals (CI95%) around the mean counts. The two significance values on each plot are for changes in the mean counts during the period 2005 to 2019 and changes between 2009 and 2017.

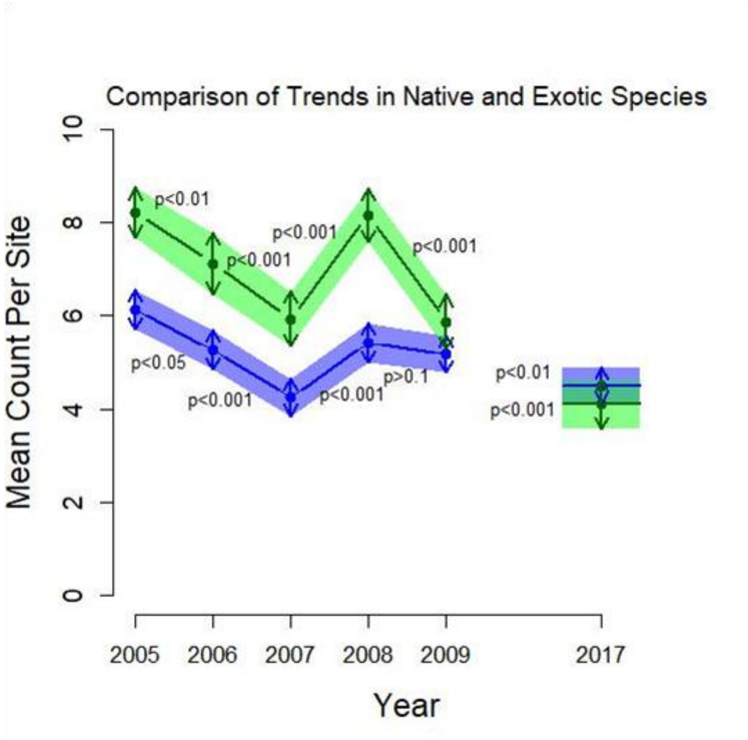


Figure 5. Comparison of trends in the mean counts of native (blue) and exotic (green) species recorded by Observer A during the six annual surveys 2005 to 2017. Coloured areas and arrows show the 95% confidence intervals (CI95%) around the mean counts. Significance levels are for comparisons between counts from successive surveys

Table 4. Mean counts of native and exotic species for Observer A's surveys 2005 to 2017. Percent change is the change since the previous survey and the *p*-level is the significance of the changes in a GLMM with Poisson errors. *% Obs.* Native is the percentage of observations that are of native species.

	All Native Species Combined					All Exotic Species Combined					
Year	N. Sp.	Mean	*(CI95%)*	% Change		N. Sp.	Mean	*(CI95%)*	% Change		% Obs. Native
2005	6	6.13	*(5.7–6.5)*			8	8.21	*(7.7–8.7)*			43%
2006	6	5.27	*(4.8–5.7)*	-14%	*	9	7.12	*(6.5–7.8)*	-13%	**	43%
2007	7	4.25	*(3.9–4.7)*	-19%	***	9	5.93	*(5.3–6.5)*	-17%	***	42%
2008	6	5.41	*(5.0–5.8)*	27%	***	9	8.15	*(7.6–8.7)*	38%	***	40%
2009	6	5.17	*(4.8–5.6)*	-5 %	NS	9	5.87	*(5.3–6.4)*	-28%	***	47%
2017	7	4.50	*(4.1–4.9)*	-13 %	**	9	4.10	*(3.6–4.6)*	-30%	***	52%

NS ~ *p*>0.1; * ~ *p*<0.05; ** ~ *p*<0.01; *** ~ *p*<0.001

Density Estimates from Distance Sampling Analyses for Native Species 2005 to 2017

Distance sampling methods were used to obtain density estimates for the four common native species (bellbird, fantail, silvereye and grey warbler) from observations recorded by Observer A during the six surveys 2005 to 2017 (Table 5 and Figure 6). A half-normal detection function was used in the best models for all analyses using observations allocated to two distance interval. However, detection functions used in the best models for analyses of three-interval observations varied, with hazard- rate detection functions used in some analyses and half-normal in others (Table 5). Models with the half-normal detection functions failed to converge for bellbird observations from all surveys from 2006 to 2017 and for warbler observations from the 2007 and 2008 surveys. Failure to converge is usually an indication that the distribution of observed distance data does not fit the underlying assumption of distance modeling that the probability of an individual being observed decreases with distance from the observer.

Density estimates obtained using data with the original three intervals were generally similar to estimates obtained using only two distance intervals (created by pooling the first two intervals). Exceptions were density estimates for silvereye in 2017 and warbler during surveys 2006 to 2008 where estimates using three distance intervals were much higher than the comparable estimates using two distance intervals. They also had had extremely wide confidence intervals and high coefficients of variability, which indicate that despite being the best, or only, model, the models were a poor fit and should be rejected.

Comparing Trends in five-minute Bird Counts and Density Estimates for Native Species 2005 to 2017

Counts from five-minute bird counts and density estimates obtained using distance sampling methods are not directly comparable. Counts from five-minute bird counts are indices, which are assumed to be proportional to actual population densities, while density estimates obtained using distance sampling methods are supposedly actual estimates of population densities. If the assumptions underlying the two methods are fulfilled, the same trends should be apparent in time-series of five-minute bird counts and density estimates for a species. Trends in the time-series of five-minute bird counts and density estimates obtained using two distance intervals are quite similar for the four common native species (Figure 6; and Tables 2, 3 and 5). The most significant deviations between the two trend lines are for fantail, in 2005 and 2017, and grey warbler, in 2007 and 2017.

Plots of Observer A's five-minute bird counts against density estimates for the four native species during the six surveys 2005–2019 and 2017 (Figure 7) show a similar pattern. There is good correlation (correlation coefficient 0.89; *p*-value <0.001) between mean counts and density estimates from distance sampling analyses using two distance intervals (Figure 7a), but poor correlation (correlation coefficient 0.38; *p*-value <0.1) between mean counts and density estimates from distance sampling analyses using three distance intervals (Figure 7b). The most extreme departures from linear relationship between mean count and density estimates from three intervals were for grey warbler in 2007 and 2008. Both of these density estimates were obtained from best models using a hazard-rate detection function and have extremely wide confidence intervals around them (Figure 5).

Table 5. Best density estimates from distance sampling analyses for four native species for the six surveys 2005 to 2017. All data are from Observer A. Results are from analyses using three and two distance intervals (a & b) respectively. The letter R denotes analyses where the hazard-rate key function provided the best model. In all other analyses the half-normal key function provided the best model.

a)

3 Intervals		Best Density Estimates - N/Ha *(CI95%)*			
Year	*N*	BELLBIRD	FANTAIL	SILVEREYE	WARBLER
2005	117	*R* 3.70 *(2.6–4.7)*	0.40 (0.2–0.6)	1.63 (1.1–2.1)	0.26 *(0.1–0.4)*
2006	120	*R* 3.24 *(2.2–4.3)*	0.44 (0.2–0.7)	0.70 (0.4–1.0)	*R* 2.80 *0–16.0)*
2007	123	*R* 2.89 *(1.7–4.0)*	0.32 (0.1–0.5)	*R* 0.47 (0.3–0.6)	*R* 12.5 *(0–167)*
2008	123	*R* 3.83 *(2.7–5.0)*	0.14 (0–0.3)	1.11 (0.7–1.5)	*R* 8.61 *(0–165)*
2009	126	*R* 3.91 *(2.7–5.1)*	0.20 (0–0.4)	0.87 (0.6–1.2)	0.47 *(0.3–0.6)*
2017	123	*R* 5.44 *(3.0–7.9)*	1.18 (0.6–1.8)	*R* 4.66 (0.8–8.6)	*R* 1.27 *(0.3–2.3)*

b)

2 Intervals		Best Density Estimates - N/Ha *(CI95%)*			
Year	N	BELLBIRD	FANTAIL	SILVEREYE	WARBLER
2005	117	3.05 *(2.5–3.6)*	0.41 *(0.2–0.6)*	1.65 *(1.1–2.2)*	0.26 *(0.1–0.4)*
2006	120	2.45 *(2.0–2.9)*	0.43 *(0.2–0.7)*	0.72 *(0.5–1.0)*	0.48 *(0.3–0.6)*
2007	123	1.83 *(1.5–2.2)*	0.33 *(0.1–0.6)*	0.69 *(0.4–1.0)*	0.49 *(0.3–0.7)*
2008	123	2.85 *(2.4–3.3)*	0.14 *(0.0–0.3)*	1.09 *(0.7–1.5)*	0.35 *(0.2–0.5)*
2009	126	2.76 *(2.3–3.2)*	0.21 *(0.1–0.4)*	0.88 *(0.6–1.2)*	0.47 *(0.3–0.6)*
2017	123	2.38 *(1.9–2.8)*	0.92 *(0.3–1.6)*	1.34 *(1.0–1.7)*	0.66 *(0.4–0.9)*

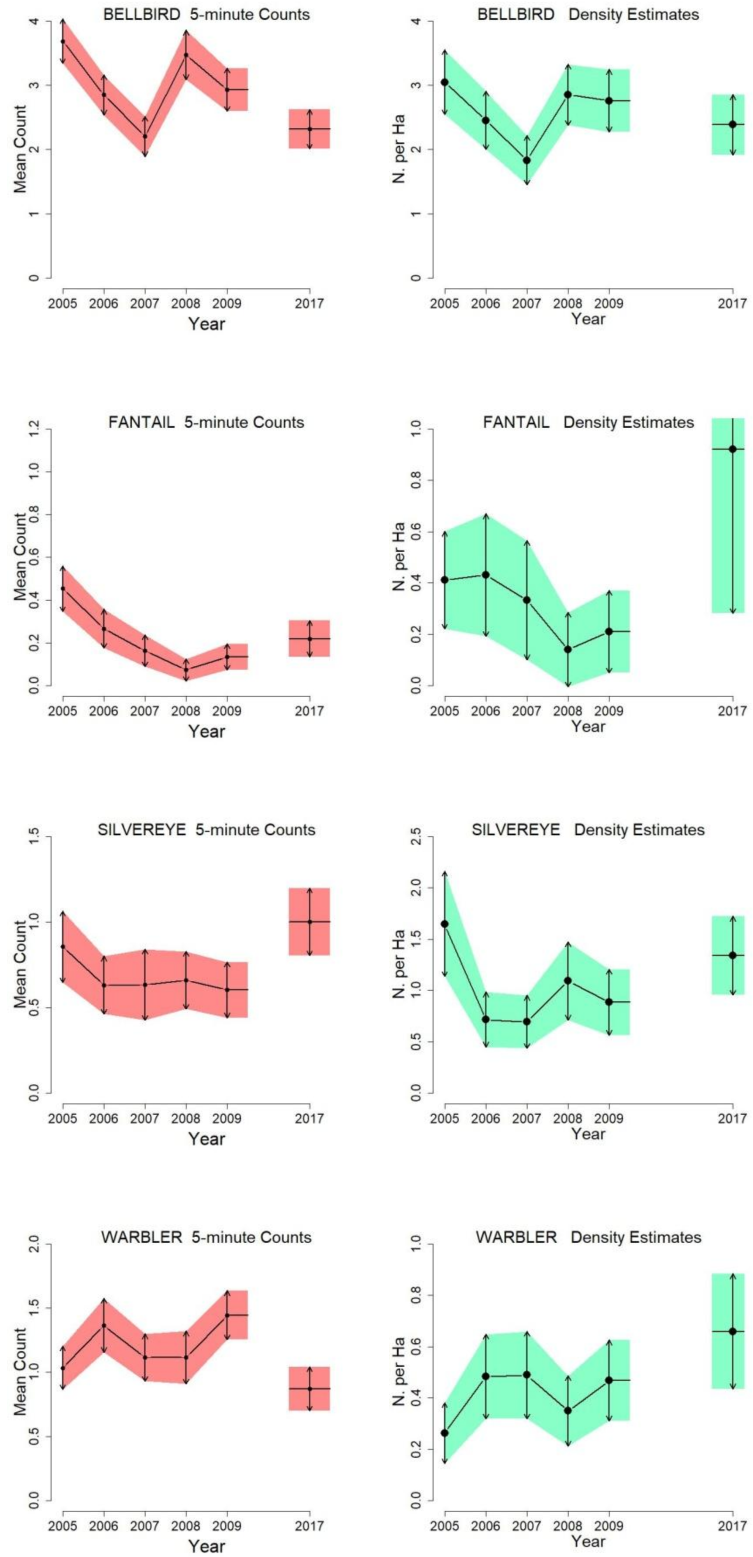


Figure 6. Comparisons of trends in five-minute counts and density estimates obtained from distance analyses with two distance intervals for the four common native species 2005 to 2017.

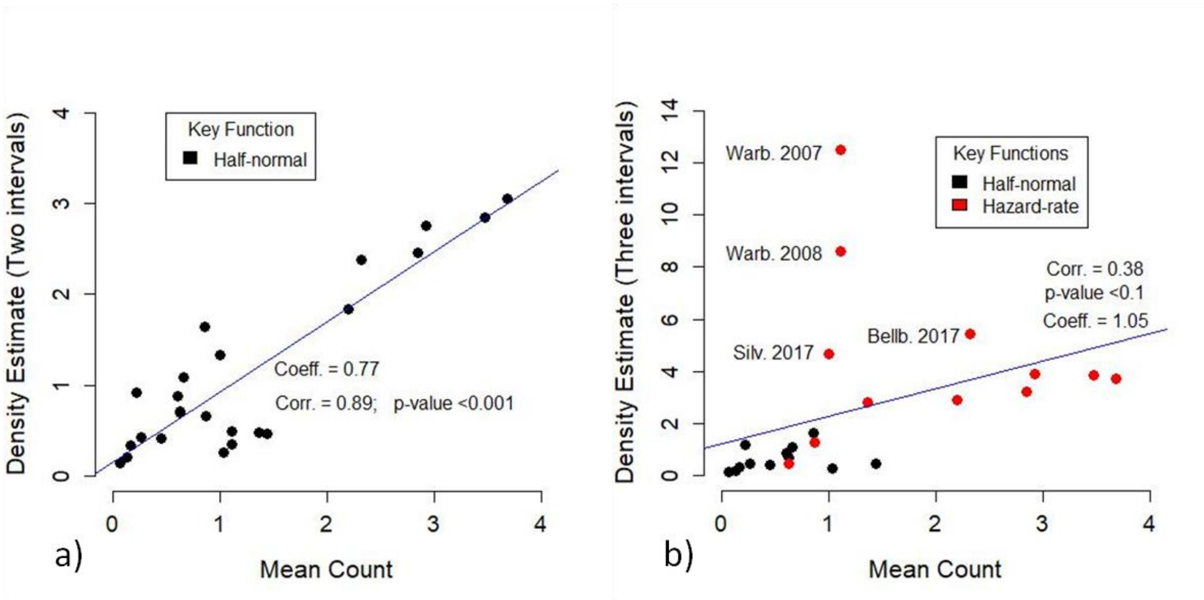


Figure 7 a & b. Plots of Observer A's mean counts against density estimates for native species, 2005 to 2017. Density estimates are from distance sampling with (a) two and (b) three distance intervals.

Trends in Species Composition

Although there were minor fluctuations in the species compositions of observations by Observer A during the period 2005 to 2017, the various diversity indices showed relatively little variation between years. Species richness showed little change throughout the thirteen-year period, with: 14 species during the 2005 survey, 15 species during the 2006, 2008 and 2009 surveys, and 16 species during the 2007 and 2017 surveys (Table 4). Shannon diversity index (Hill, 1973), which characterizes species richness and equitability in distribution, showed little variation other than a minor dip in 2007 (Figure 8). Simpson's index and inverse index showed similar trends to Shannon's index. By contrast, values of Fisher's α parameter (Fisher et al. 1943), a measure of biodiversity, fluctuated between 2.1 and 2.7 with peaks of 2.6 and 2.7 in 2007 and 2017 respectively (Figure 8). These relatively minor increases in biodiversity values were probably in response to both the greater number of species in 2007 and 2017 and a reduction in differences in the relative abundances of common species in 2017.

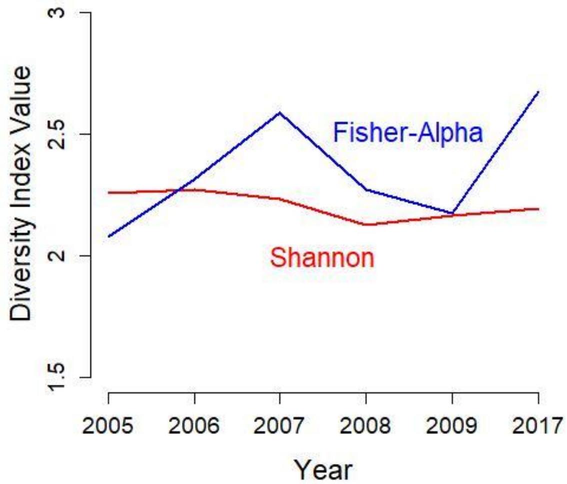


Figure 8. Diversity indices for the six surveys undertaken by Observer A, 2005–2017.

Values of the Bray-Curtis dissimilarity index (Figure 9) showed results from 2017 were different to those from the other five years. Values of the dissimilarity index for comparisons between 2017 and the other five years were all higher (>0.06) than values for comparisons among the other five years, with the exception of a comparison between 2005 and 2007, which had a dissimilarity index value of 0.07.

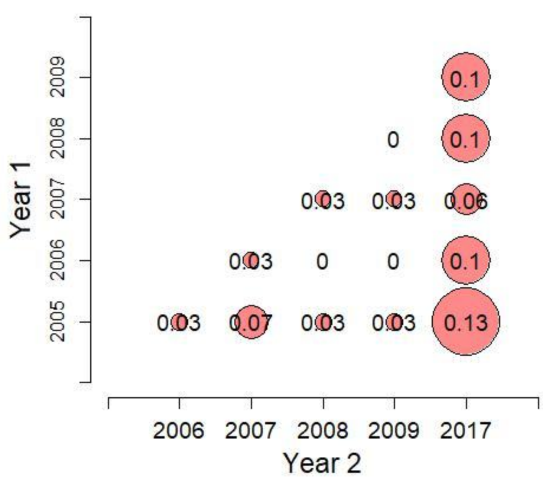
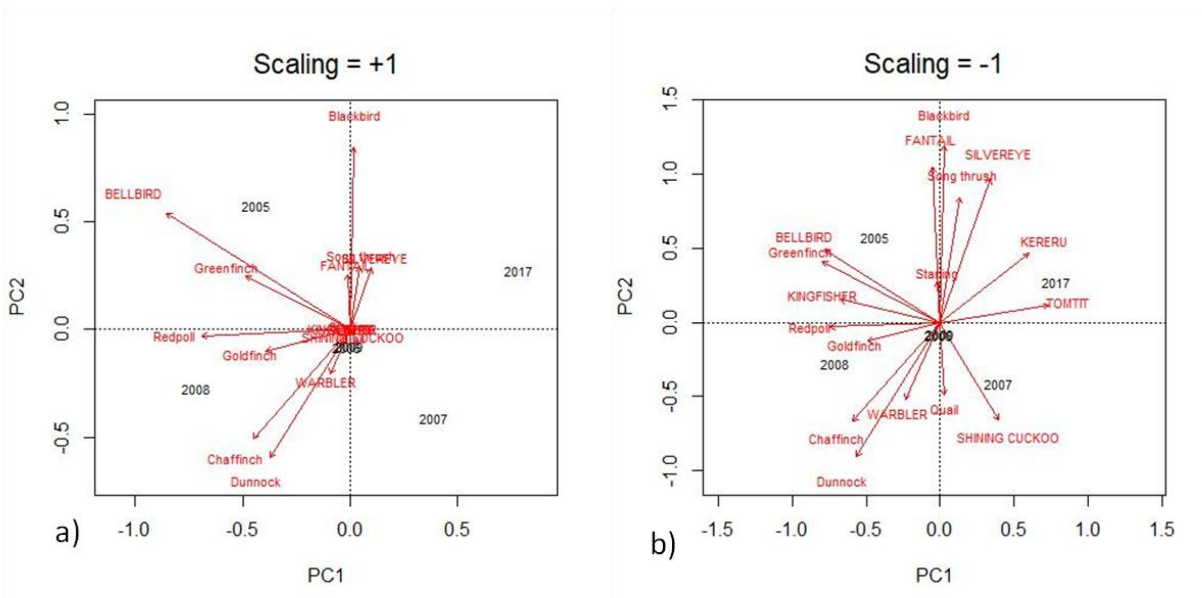


Figure 9. Bray-Curtis dissimilarity indices for the six surveys undertaken by Observer A, 2005–2017

Results from ordination analyses confirmed the distinctiveness of the 2017 observations, with 2017 lying well to the right of all other years on the primary component's (i.e. horizontal axes) of the Principal Components Analyses (PCA) ordination plot (Figure 10 a & b). The 2007 observations are also separate from other years in the ordination plots, sitting alone in the bottom right quadrant of the ordination. Figures 10a and 10b both show the results of the same PCA. In Figure 10a species scores are un-scaled, consequently rare species' scores all cluster close to the origin and are illegible. In Figure 10b rare species scores have been made legible by rescaling species scores. This entails dividing species' scores by their standard deviations to place abundant and rare species at similar distances from origin. Vectors for the common species in the un-scaled PCA ordination plot (Figure 10a) all show there were fewer observations of common species during the 2007 and 2017 surveys than during survey in the other four years. The influence of rare species on the ordination is apparent in the re-scaled PCA ordination plot (Figure 10b), with: shining cuckoo observed in 2007; and shining cuckoo, tomtit, and kereru all observed in 2017.



Figures 10 a & b. Bi-plots of Principal Components Analyses (PCA) for the six surveys undertaken by Observer A, 2005–2017; using: (a) un-scaled species scores; and (b) rescaled species scores with scores divided by standard deviations so that abundant and rare species are similar distances from the origin.

The Influence of Weather Conditions

Plots of the five-minute bird counts against weather scores indicate that counts are affected by weather conditions (Figure 11). Multi-way GLMMs were used to investigate the influences of survey year and values of the five weather variables (rain, wind, noise, sun and temperature) at the time of the counts using Model 1[2].

In GLMMs with all species counts combined and all common species counts combined, the variables year and rain were significant (p<0.001 and p<0.05), whereas the other weather variables (wind, noise, sun and temperature) were not significant (p>0.1). In separate GLMMs for each of the 11 common species (2005 to 2017), year was significant (p<0.001) for all species whereas significance levels for the two weather variables, wind and rain, varied by species (Table 6). Counts for most species were significantly lower when there were higher wind and rain scores during the surveys. However, counts of silvereye and warbler weren't significantly affected by any of the weather variables, while counts of fantail and dunnock were affected by wind, but not by rain.

Table 6. Probability levels for three variables in GLMMs of the counts of common species for all surveys by Observer A during the period 2005 to 2017.

Species	Variable		
	Year	Wind	Rain
BELLBIRD	***	**	***
FANTAIL	***	*	*NS*
SILVEREYE	***	*NS*	*NS*
WARBLER	***	*NS*	*NS*
Blackbird	***	***	**
Song thrush	***	***	**
Chaffinch	***	*NS*	**
Goldfinch	***	*NS*	**
Greenfinch	**	***	***
Redpoll	***	***	***
Dunnock	***	**§**	*NS*
Common Species:	***	NS	*
All Species:	***	NS	*

NS ~ p>0.1; **§** ~ p<0.1;
* ~ p<0.05; ** ~ p<0.01; *** ~ p<0.001

[2] Model 1: Total Count~Year+Wind+Rain+Noise+Sun+Temp+(1|PointID), family=Poisson

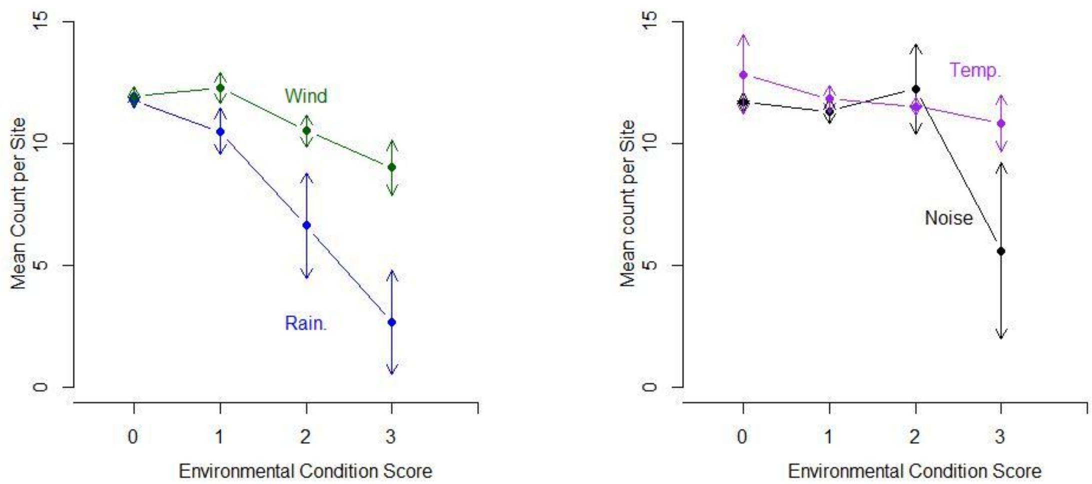


Figure 11. Changes in mean counts of all species combined in response to weather conditions during the six surveys 2005 to 2017.

Because weather conditions during surveys were different each year, values of year and the weather variables are not independent. This multi-collinearity confounds the effects of year and the weather variables in regression models. In separate GLMMs of the weather variables wind and rain for each year, the weather variables did not have a significant effect ($p>0.1$) except for the low levels of rain in 2008 ($p<0.05$). This result indicates that the apparent influence of rain and wind in GLMM's including both year and the weather variables is an artifact arising from differences in the weather scores between years, not a direct influence of rain or wind on counts.

Comparing the Two Observers Results for the 2017 Surveys

During 2017, surveys were undertaken by two observers (Observer A and B) working together recording simultaneous, but independent, counts at each site. The two observers undertook three replicates surveys along twelve of the transects and five replicates along one transect. Thus, during 2017, each observer undertook 123 five-minute bird counts.

First heard/first seen

The two observers both recorded sixteen bird species during five-minute bird counts in 2017. There was little difference between the two observers in the proportions of observations where birds were first heard, with 96.2% of Observer A's observations and 97.8 % Observer B's observations being of birds that were heard first.

Mean counts

Observer A's total mean counts were significantly (*p*<0.001) lower than Observer B's for all species pooled (-15%) and for all common species pooled (-15%) (Table 3). For the 11 common species, differences between the two observer's counts of individual species (Table 3 and Figure 12) were not significant for five species: bellbird, blackbird, goldfinch, redpoll and song thrush. However, Observer A's counts were significantly higher than Observer B's counts for two species: chaffinch (19%) and greenfinch (32%); and significantly lower than Observer B's counts for four species: fantail (-74%), silvereye (-90%), warbler (-48%) and dunnock (-116%).

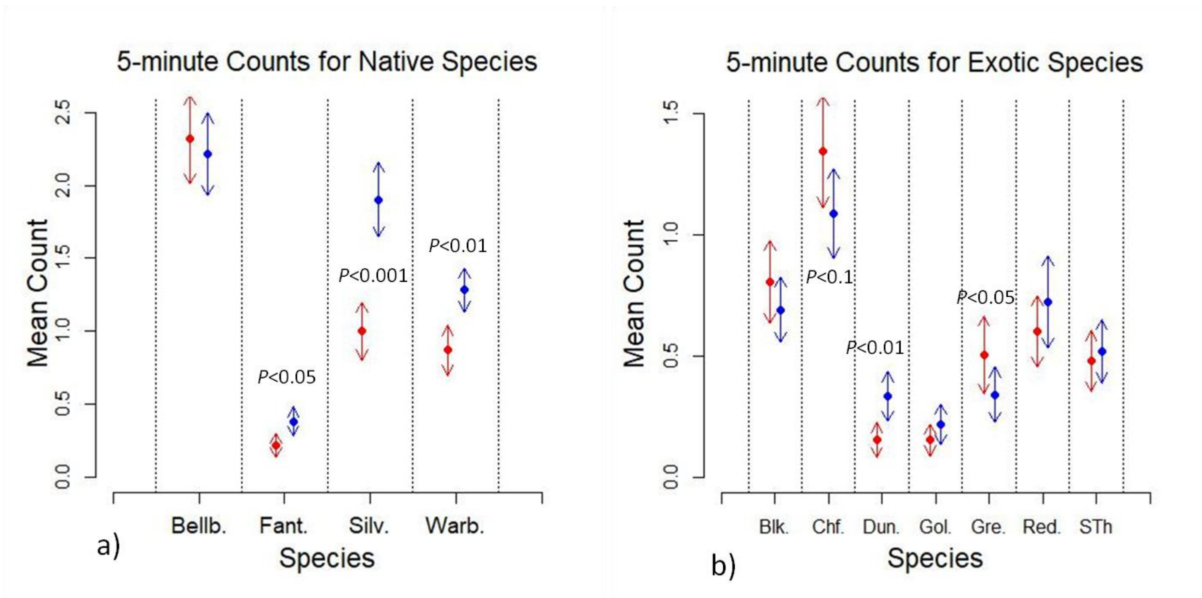


Figure 12. Comparisons of mean five-minute bird counts from Observer A (red) and Observer B (blue) for native (a) and exotic (b) species. Arrows show the extent of the 95% confidence intervals around mean counts.

Comparing observer's density estimates from distance analyses

Distribution of observation among the three distance intervals

The allocation of observations among distance intervals has a major influence on the size of density estimates obtained from distance sampling analyses. Typically, small increases in the proportion of observations allocated to the furthest distance intervals will cause large decreases in density estimates obtained from distance analyses.

Allocations to the three distance intervals (0–20 m, 20–50 m and 50–200 m) by the two observers were significantly different (Chi-square test of independence: *p*<0.001), with Observer B allocating more observations to the 20–50 m interval and fewer to the other two intervals (Table 7). This pattern holds for individual species, with Observer B having higher proportions of observations in the middle distance interval for all of the eleven common species (Table 7).

Another distinction between the observer's allocations of observations among the three distance intervals is the much higher (45% – 66%) proportions of Observer A's observations allocated to the furthest distance interval (i.e. 50–200 m) for three finch species: goldfinch, greenfinch and redpoll.

Table 7. Proportions of observations allocated to the three distance intervals (0–20 m, 20–50 m and 50–200 m) for the eleven common species, arranged by difference in the proportion of observations in the third distance interval.

	Observer A			Observer B			Difference (%A-%B)		
Distance Interval:	0–20	20–50	>50	0–20	20–50	>50	0–20	20–50	>50
Species									
Goldfinch	0.0	15.8	84.2	11.1	70.4	18.5	-11.1	**-54.6**	**65.7**
Greenfinch	3.2	19.4	77.4	2.4	69.0	28.6	0.8	**-49.7**	**48.8**
Redpoll	0.0	5.4	94.6	1.1	49.4	49.4	-1.1	**-44.0**	**45.2**
Chaffinch	6.1	23.0	70.9	7.4	33.8	58.8	-1.3	-10.8	12.1
SILVEREYE	35.0	30.1	35.0	21.4	53.0	25.6	13.6	-22.9	9.3
Song thrush	6.8	10.2	83.1	4.7	18.8	76.6	2.1	-8.6	6.5
Blackbird	14.1	24.2	61.6	5.9	37.6	56.5	8.3	-13.4	5.1
BELLBIRD	23.5	31.9	44.6	21.7	33.8	44.5	1.8	-1.9	0.1
WARBLER	15.9	29.0	55.1	8.2	32.3	59.5	7.7	-3.3	-4.4
Dunnock	26.3	42.1	31.6	7.3	53.7	39.0	19	-11.6	-7.4
FANTAIL	55.6	40.7	3.7	21.3	46.8	31.9	34.3	-6.1	-28.2

All species	Observer A			Observer B		
Interval:	0–20	20–50	>50	0–20	20–50	>50
Mean:	18.1	24.9	56.9	10.6	38.9	50.5
(CI95%)	*(6–30)*	*(14–36)*	*(42–72)*	*(0–21)*	*(27–51)*	*(37–64)*

Distance analyses with observer as a covariate

To investigate whether the observer's density estimates were significantly different, distance models with, and without, observer as a covariate were fitted to pooled distance observations from the two observers for each species. Separate analyses were undertaken using data allocated to two and three distance intervals.

The number of distance intervals that observations were allocated to had little effect on whether observer was included as a covariate in the best model for nine of the eleven species (Table 8). There were five species where the best model for both data sets included observer as a covariate (fantail and the four finch species: chaffinch, goldfinch, greenfinch and redpoll) and four species where the best model didn't include observer as a covariate (bellbird, blackbird, dunnock and song thrush). However, there were two species (silvereye and warbler) where the best model for two- and three-interval data differed. In both these cases the best models for the two-interval data sets didn't include observer as a covariate, whereas best models for three-interval data included observer as covariate.

Table 8 includes estimates of the scale coefficients for the detection function in distance models including observer as a covariate. Positive values indicate density estimates from Observer A are higher than estimates from Observer B. Conversely, negative values indicate density estimates from Observer A are lower than estimates from Observer B. The scale coefficients had positive values for two (fantail and warbler) of the seven species where observer was included in the best model as a covariate and negative values for the other five species (silvereye and the four finch species). Thus, the results indicate that density estimates from Observer A's observations are higher than density estimates from Observer B's observation for fantail and warbler, but lower for silvereye and the four finch species.

Table 8. The results of distance analyses with observer as a covariate and observations allocated to two and three distance intervals. Positive values for the scale coefficient indicate density estimates from Observer A are higher than estimates from Observer B. Conversely, negative values indicate density estimates from Observer A are lower than estimates from Observer B.

	Key Function*		Best Model		Observer Scale Coefficient *(SE)*			
Distance Intervals:	Two	Three	Two	Three	Two		Three	
BELLBIRD	*N*	*R*	~1		-0.001	*(0.058)*	0.058	*(0.135)*
FANTAIL	*N*	*N*	~Observer		**0.530**	*(0.176)*	**0.636**	*(0.128)*
SILVEREYE	*N*	*R*	~1	~Observer	-0.129	*(0.071)*	0.181	*(0.105)*
WARBLER	*N*	*R*	~1	~Observer	0.068	*(0.097)*	0.319	*(0.203)*
Blackbird	*N*	*N*	~1		-0.083	*(0.117)*	-0.053	*(0.115)*
Chaffinch	*N*	*N*	~Observer		-0.219	*(0.101)*	-0.215	*(0.100)*
Dunnock	*N*	*N*	~1		0.101	*(0.180)*	0.163	*(0.170)*
Goldfinch	*N*	*R*	~Observer		**-1.188**	*(0.397)*	**-0.821**	*(0.285)*
Greenfinch	*N*	*R*	~Observer		**-0.805**	*(0.175)*	**-0.576**	*(0.161)*
Redpoll	*N*	*R*	~Observer		**-6.853**	*(51.6)*	**-1.454**	*(682)*
Song thrush	*N*	*N*	~1		-0.208	*(0.242)*	-0.195	*(0.235)*

*~ Function is the key function used in the best distance model: *N* = Half-normal; *R* = Hazard-rate.

Separate distance analyses of the two observers distance observations

Results from separate analyses of the two observers distance observations (Table 9 and Figure 13) provided a similar pattern to results from distance analyses with observers as a covariate (Table 8). In the separate analyses, the two observers' density estimates were similar for bellbird, and warbler, but different for fantail and silvereye. Extensive overlap in 95% confidence intervals around the observers' density estimates for bellbird, and warbler indicate that differences between the two observer's estimates for these two species were not significant. Results for fantail and silvereye were not as clear cut. Both of Observer A's density estimate for fantail were higher than Observer B's (0.92 vs. 0.56/ha for two-interval data and 1.18 vs. 0.58/ha for three-interval data). However, there was extensive overlap between 95% confidence intervals around density estimates from the two-interval data, but little overlap in estimates from three-interval data. Results from analyses for silvereye were even more contradictory. In analyses of two-interval data, estimates from Observer A were higher than estimates from Observer B, whereas in analyses of three-interval data estimates from Observer A were lower (1.3 vs. 3.3/ha and 4.7 vs. 3.3/ha). There was no overlap between 95% confidence intervals around estimates from two-interval data, but extensive overlap in estimates from the three-interval data.

Table 9. Density estimates from separate distance analyses for the two observers and observations allocated to two and three distance intervals.

	Density Estimates (N/Ha) with 95% Confidence Intervals *(CI95%)*									
	Two Intervals				Three Intervals					
Species	Observer A		Observer B			Observer A			Observer B	
	N/Ha	*(CI95%)*	N/Ha	*(CI95%)*		N/Ha	*(CI95%)*		N/Ha	*(CI95%)*
BELLBIRD	2.38	*(1.9–2.8)*	2.28	*(1.8–2.7)*	**R*	5.44	*(3.0–7.9)*	*R*	4.37	*(2.6–6.1)*
FANTAIL	0.92	*(0.3–1.6)*	0.56	*(0.3–0.8)*		1.18	*(0.6–1.8)*		0.58	*(0.3–0.8)*
SILVEREYE	1.34	*(1.0–1.7)*	3.30	*(2.6–4.0)*	*R*	4.66	*(0.8–8.6)*		3.35	*(2.7–4.0)*
WARBLER	0.66	*(0.4–0.9)*	0.85	*(0.6–1.1)*	*R*	1.27	*(0.3–2.3)*		0.85	*(0.6–1.1)*
Blackbird	0.50	*(0.3–0.7)*	0.50	*(0.3–0.7)*	*R*	1.23	*(0.0–2.7)*		0.49	*(0.3–0.7)*
Chaffinch	0.59	*(0.4–0.8)*	0.75	*(0.5–1.0)*		0.59	*(0.4–0.8)*		0.74	*(0.5–1.0)*
Dunnock	0.23	*(0.1–0.4)*	0.40	*(0.2–0.6)*		0.24	*(0.1–0.4)*		0.38	*(0.2–0.6)*
Goldfinch	0.03	*(0.0–0.1)*	0.47	*(0.2–0.8)*		0.03	*(0.0–0.1)*		0.42	*(0.2–0.7)*
Greenfinch	0.16	*(0.1–0.3)*	0.54	*(0.3–0.8)*		0.16	*(0.1–0.3)*	*R*	0.31	*(0.2–0.4)*
Redpoll	0.05	*(0.0–0.1)*	0.65	*(0.4–0.9)*		0.05	*(0.0–0.1)*	*R*	0.47	*(0.3–0.6)*
Song thrush	0.11	*(0.0–0.2)*	0.18	*(0.1–0.3)*		0.12	*(0.0–0.2)*		0.18	*(0.1–0.3)*

*~ *R* denotes analyses with a hazard-rate key function in the best distance model.

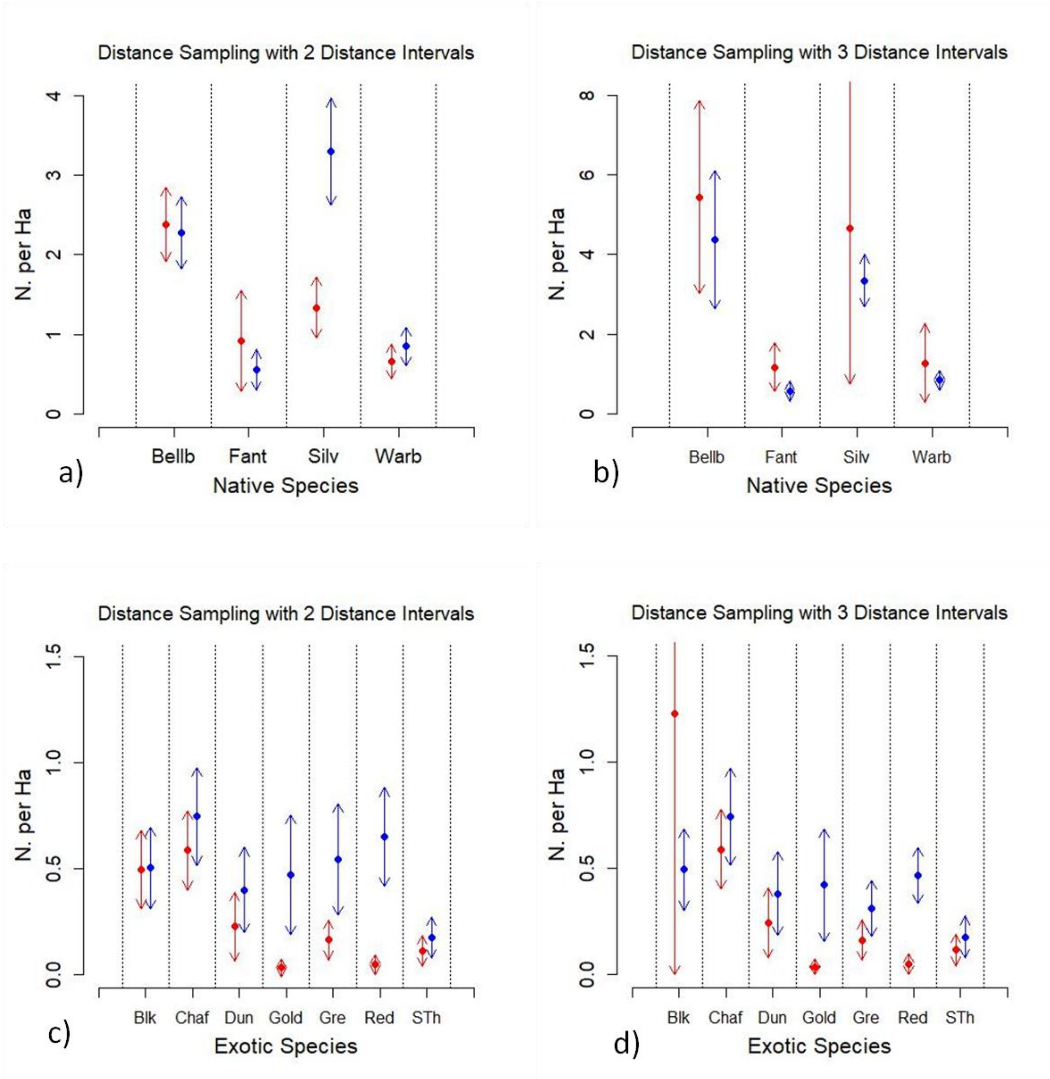


Figure 13 a – d. Comparisons of density estimates from Observer A (red) and Observer B (Blue) for native and exotic species using data allocated to two and three distance intervals. Arrows show the extent of the 95% confidence intervals around density estimates.

Observer B's density estimates were higher than Observer A's for all the exotic species except blackbird. Blackbird density estimates from the two observers were the same (0.50/ha) for analyses using two-interval data, but different for analyses using three-interval data, with higher estimates from Observer A (1.23/ha vs. 0.49/ha). However, extensive overlap between the 95% confidence intervals of the two observers' estimates for blackbird, chaffinch and dunnock indicate that differences between density estimates from the two observers are not significant. Differences between the two observer's density estimates are significant for goldfinch, greenfinch and redpoll, as there is little or no overlap between 95% confidence intervals around the two observers' density estimates from both two and three-interval data.

It should be noted that in most distance analyses, the best model had a half-normal key function. The half-normal key function was used in the best models for all twenty-four analyses of two-interval data and seventeen of the twenty-four analyses of three-interval data. Typically, models with the hazard-rate key function were only selected as best models because alternative models with the half-normal key function failed to converge. Failure to converge usually happens when the distribution of observations between the distance intervals does not fulfill the underlying assumptions of distance sampling about detection probabilities declining with distance from the observer. For the data in these analyses, the hazard-rate key function proved more robust than the half-normal function, as all hazard-rate models converged successfully. However, comparison between estimates from models with half-normal and hazard-rate key functions is problematic. Modeling the effect of changing the allocations of observations between the three distance showed that the hazard-rate function was unstable when used to analyse data from Observer A. Minor changes of less than 10% in the numbers allocated to the three intervals around the mean allocations for the two observers had relatively little effect on estimates obtained with the half-normal function, or estimates obtained from Observer B's data with the hazard-rate function, but had large effects on density estimate obtained from Observer A's data with the hazard-rate function.

Comparing observer comparisons of mean counts and distance estimates

There were few consistent patterns in comparisons of the percentage differences between observers mean counts and density estimates (Table 10). In all three sets of comparisons, differences between the two observers were not significant for three species: bellbird, blackbird and song thrush. Although differences between observers were not significant for any of these comparisons, Observer A's estimates were all higher for bellbird and blackbird, while Observer B's estimates were all higher for song thrush. Observer B's estimates were higher in all three comparisons for dunnock, but the differences were only significant for mean counts.

The three sets of comparisons of the observers' results for the four finch species (chaffinch, goldfinch, greenfinch, and redpoll) show an interesting pattern. Differences between mean counts and density estimates for all four finch species, show the same shift: from small and usually not-significant differences between the mean counts to significant, mostly large, differences between density estimates, with Observer A's density estimates lower than Observer B's. This difference in density estimates is presumably a consequence of the high proportions of observations Observer A allocated to the furthest distance intervals for the four finch species (Table 7). Typically, increasing the proportion of observations in the furthest distance intervals reduces density estimates from distance analyses.

Table 10. Comparisons of the percentage differences between observers for mean counts and distance sampling density estimates obtained using two and three distance intervals. Negative values for difference (i.e. red font) indicates that estimates from Observer A are lower than those for Observer B. The significance levels are for comparison between observers estimates of mean counts and density.

	Percentage Differences between Observers					
	5-Minute Bird Counts		Density Estimates			
			Two Intervals		Three Intervals	
BELLBIRD	5%	*NS*	4%	*NS*	20%	*NS*
FANTAIL	-74%	*	40%	*	51%	*
SILVEREYE	-90%	***	-146%	*NS*	28%	*
WARBLER	-48%	**	-29%	*NS*	33%	*
Blackbird	14%	*NS*	0%	*NS*	60%	*NS*
Chaffinch	18%	§	-27%	*	-26%	*
Dunnock	-116%	**	-76%	*NS*	-56%	*NS*
Goldfinch	-42%	*NS*	-1,305%	*	-1,176%	*
Greenfinch	32%	§	-232%	*	-90%	*
Redpoll	-20%	*NS*	-1,256%	*	-873%	*
Song thrush	-8%	*NS*	-57%	*NS*	-53%	*NS*

NS ~ p>0.1; **§** ~ p<0.1; * ~ p<0.05; ** ~ p<0.01; *** ~ p<0.001

Conflicting results of comparisons between density estimates from two- and three-interval data for silvereye, and warbler is probably a consequence of the different key functions used in the best models for Observer A's two- and three-interval data. In both species, density estimates from two-interval data came from best models with a half-normal key function, while estimates from three-interval data came from best models with a hazard-rate key function. This was because models with a half-normal key function failed to converge. As discussed above, modeling has shown density estimates obtained from Observer A's three-interval data using distance models with a hazard-rate key function are unreliable. Comparisons between observers mean counts and their density estimates from two-interval data for silvereye, and warbler are similar. Both show estimates from Observer A were significantly lower than estimates from Observer B.

Although there were few consistent patterns in comparisons of the percentage differences between observers, plots of mean counts against density estimates for the 11 common species observed in 2017 show good correlation (correlation coefficients 0.84 & 0.80; p-values <0.001) between mean counts and density estimates from distance sampling with either two or three distance intervals (Figure 14 a & b). The most extreme departure from linear relationship between mean count and density estimates was for Observer A's estimates for silvereye using distance sampling with three distance intervals (Figure 14 b). The density estimate for silvereyes was from a best model with a hazard-rate detection function and has a wide confidence interval around it.

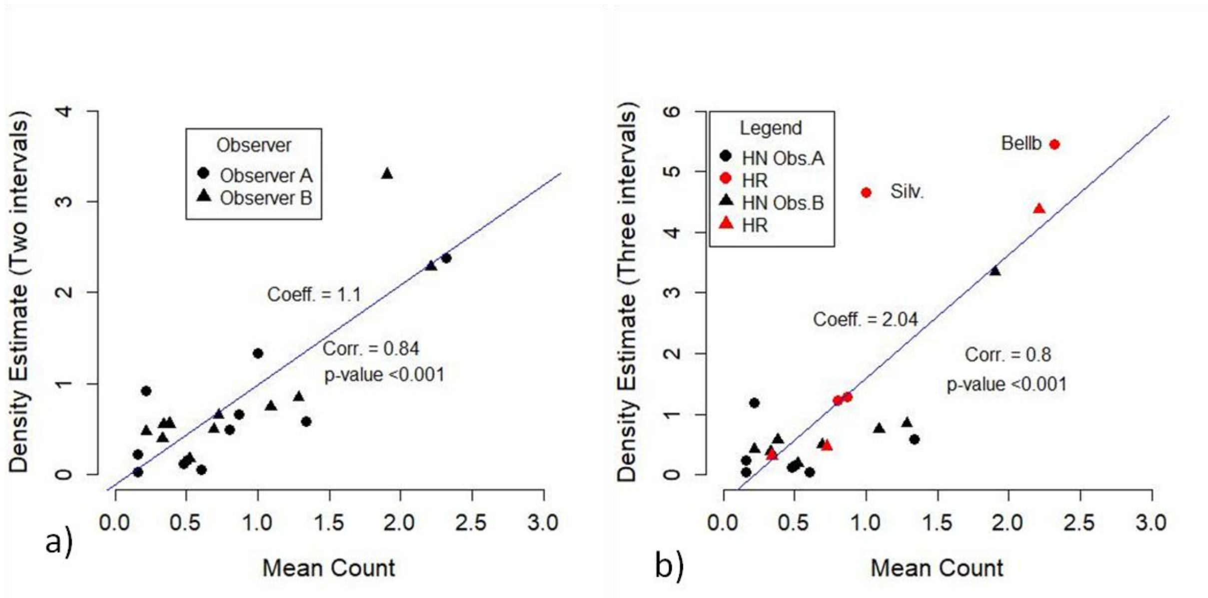


Figure 14. Plots of mean counts against density estimates for Observer's A and B 2017. Density estimates are from distance sampling with (a) two and (b) three distance intervals.

Waterfowl and Wetland Birds

Waterfowl

A total of 275 waterfowl were counted on the three water bodies over three counts (Table 11). Canada geese were the most common species, followed by scaup, shoveler and mallard. Six ducks observed in the area were either nationally critical grey ducks or mallard-grey duck hybrids. Facial stripes on the ducks were typical of the pure grey duck phenotype. Unfortunately, the ducks were too far away to observe their speculum for additional confirmation of their phenotype.

Table 11: Total numbers of waterfowl counted during three counts at each water body over three counts

Waterfowl Species	Ella Pond	Kate Pond	Water Supply Pond	Total
SCAUP	16	18	11	45
GREY TEAL	9	3	0	12
GREY DUCK (?)	3	2	1	6
SHOVELER	24	13	5	42
PARADISE SHELDUCK	0	4	0	4
Mallard	17	14	15	46
Canada goose	5	63	5	73
BLACK SWAN	7	6	6	19
WHITE FACED HERON	0	1	1	2
WELCOME SWALLOW	12	12	2	26
Total	93	136	46	275

Wetland birds

No bittern or fernbird were detected during playback surveys or during reviews of acoustic recordings. At least seven spotless crake were heard on the water supply dam and Kate Pond over the three days of the survey (Figure 14). Seven were heard on one evening (11 October 2017), so there is unlikely to be overestimation due to birds moving between ponds. They were quite responsive to playback, particularly with the quiet contact ‘chucks’, but also the loud ‘churrrr’ call. Best results seemed to be obtained by playing calls at a moderate volume and waiting silently for five minutes after playback. Close range visual identification of one spotless crake calling on the top dam enabled definitive confirmation that the call being heard was from spotless crake. Crakes were only found in raupo with water underfoot. They were extremely elusive and never ventured outside the raupo. Acoustic monitoring picked up some calls, but it was clear that playback was more effective for detecting spotless crakes.

Figure 15. Spotless crake observations (blue dots) and unidentified probable spotless crake calls (red dots).

An unknown repetitive, plaintive call, probably from two separate birds, was also heard and recorded repeatedly at Ella Pond. The identity of this call is unconfirmed, but resembles some spotless crake calls found online. It is thought to be a variant call or local dialect of spotless crake due to the known presence of these birds here. It is possible, but unlikely, the call is from marsh crake. Good quality recordings of calls were obtained to enable playback with local dialect for surveys in future years. Use of local dialects is likely to increase response rate.

DISCUSSION

Bird Count Trends

The similarities in bird species compositions and diversity between the current 2017 survey and earlier surveys is not surprising given that there have not been dramatic changes in the habitat since 2005. The removal of stock and exclusion of deer has resulted in notable understory regrowth and improvements in the growth and condition of indigenous plantings. However, the plantings are still young and the forest patches are still discrete, with similar structure and composition to twelve years ago. Thus, there has been little change in the quality of bird habitat since 2005.

The significant decline in bird numbers, especially bellbirds and finches, between 2005 and 2017 cannot be easily explained. Further monitoring will be required to see whether the observed trend is part of a continuing decline or merely a cyclic fluctuation in numbers. The overall species decline is largely driven by counts of bellbirds as this species was by far the most common species counted. If the declines in counts (Figures 3, 4 & 5) reflect an actual decline in population densities, the results of studies elsewhere (e.g. Elliott et al. 2010; Elliott & Suggate 2007; Innes et al. 2010; O'Donnell 1996; O'Donnell & Hoare 2012) indicate that predators are the most probable causal agents for the declines.

The scarcity, or absence, of many indigenous forest bird species in the CMA and low comparative species diversity, is probably a consequence of the combined effects of forest fragmentation, small patch size, forest modification by browsing mammals, and high numbers of mammalian predators. It seems likely that indigenous bird species numbers and diversity will increase as natural regeneration takes its course and the forest patches are extended and connected by further planting. However, positive outcomes for native bird populations will only be achieved through robust control of mammalian predators and competitors. Predator control has been found to benefit a range of birds in New Zealand (e.g. Elliott & Suggate 2007; O'Donnell & Hoare 2012). Stoat control has been effective in increasing numbers of bellbirds (Kelly et al. 2005; Masuda et al. 2014) and rodent control has benefited populations of rodent sensitive birds such as tomtit, robin and mohua (Elliott & Suggate 2007; O'Donnell & Hoare 2012). One study found that control of ship rats and possums was sufficient to enhance nesting success of small forest birds in North Island remnant forest fragments (Innes et al. 2015).

The impact of avian predators, such as the indigenous harrier and introduced magpie, on small passerine birds and crakes within the CMA is unknown. Studies assessing the impacts of magpie on native birds indicate that magpies were not serious nest predators in rural areas compared to ship rats, cats and harriers (Morgan et al. 2006). On the other hand, harriers are important predators of forest birds such as kokako and tui (Innes et al. 1999; Morgan et al. 2006) and presumably other birds. Harriers are common and magpies relatively uncommon within the CMA.

The observation that birds such as kereru, tomtit and brown creeper are rare residents, or visit the area from time to time is encouraging, indicating that these and other species could increase their populations or colonize successfully as a result of forest regeneration and predator management.

The effects of habitat change on bird populations at the CMA have not been analysed. Surrounding pasture grasses were noticeably lusher in 2007 and subsequent years than in 2005 when stock was removed (Norton 2012). Similarly, understory shrubs have become considerably lusher in many of the forest patches. While these changes are expected to benefit birds by increasing food resource and shelter, rodent numbers are also likely to increase. For example, Hoare et al. (2007) suggested that proliferating seeding grasses after stock were removed at Pukerua Bay Scientific Reserve in 1987 may have led to periodic irruptions of rodents followed by a suite of other mammalian predators causing populations of lizards to decline. The dynamics of bird species populations in the area could be quite complex due to these and other unmonitored variables.

Differences between the count data from the two observers in 2017 are examined in detail. While the two observers generally recorded the same species during each count, there were significant differences between the numbers of individuals recorded by the two observers for several species (silvereye, grey warbler greenfinch and dunnock). There were also marked differences in each observer's ability to estimate distances. The instability of results from distance sampling analyses is assumed to be due mainly to: 1) difference in the hearing abilities of the two observers; 2) insufficient training in estimating distances to birds; and 3) the difficulty of estimating horizontal distances to birds that are heard but not seen. Difference in the hearing ability of the two observers is probably an important factor affecting both five-minute counts results and density estimates from distance sampling analyses. Age-related high frequency hearing loss is a common phenomena, especially for males. Observer A is 69 years old, whereas Observer B is 36. As a consequence Observer A will probably hear fewer high-frequency bird calls than Observer B, especially if the calls are at some distance from the observer (c. >50 m). Loss of upper frequency hearing with age is apparent in comparisons between five-minute counts from the two observers (Table 3 and Figure 12). Differences between the two observers' five-minute counts were not significant for species with lower frequency calls (e.g. bellbird, blackbird and song thrush), whereas Observer A's counts of species with higher frequency calls (e.g. fantail, silvereye, grey warbler and dunnock) were significantly lower than those of Observer B. It also seems likely that Observer A will tend to allocate calls from species with high-frequency calls to more distant intervals than they were actually in. This is apparent in the table showing the two observers' allocations to the three distance intervals (Table 7). Observer A allocated much higher proportions of observations of the three small finch species (goldfinch, greenfinch and redpoll) to the furthest distance interval than Observer B.

Waterfowl and Wetland birds

The possible presence of grey duck at Kate Valley wetlands is interesting, as the species is currently listed as Nationally Critical (Robertson et al. 2017). Grey ducks are listed as Nationally Critical, because the species hybridizes freely with introduced mallard and as a consequence purebred grey ducks are now very rare (Williams & Basse 2006). Mallard-grey duck hybrids are variable and difficult to distinguish morphologically from purebred grey ducks. This may not be possible without genetic sampling (Williams 2013).

The presence of a population of spotless crake is of national significance because it is a threatened species not formerly recorded from the area (Robertson et al. 2007) and rarely observed in the South Island (Hadden 1993, O'Donnell 1994). Records of spotless crake are scant in the South Island, but the species has been previously recorded in Canterbury: at

Leithfield Beach to the south and Mata Kopae/St Anne's Lagoon to the north (O'Donnell 1994). Typically spotless crake are found in raupo (*Typha orientalis*), or occasionally *Scirpus*, *Carex* or *Juncus* beds. From this survey and other surveys, raupo reedbeds appear to be ideal habitat for spotless crake, and there may not be enough of this remaining in Canterbury to support larger populations (O'Donnell 1994).

Spotless crake are very cryptic birds and were only recorded during 2017 because of a dedicated search using call playback. Although not statistically analysed, it is clear that call playback detected more calls than passive listening by the observer or acoustic devices. This is consistent with other surveys of marsh birds (Conway & Gibbs 2004) and reinforces the use of this method. Marsh crake may also be present and are even more cryptic than spotless crake (O'Donnell 1994).

Improving and increasing wetland habitat is important for protecting the species currently occupying them, and crucial for providing colonization opportunities for other species such as bittern. Wetland habitat has been reduced by over 90% nationwide and most wetland bird species are ranked as threatened or at-risk, including bittern and grey duck (both ranked as Nationally Critical). Kate Valley is a key component of a network of wetlands along the north Canterbury coast, and if restored further, has potential to be a focal habitat for these threatened and at-risk wetland birds. This would bolster the area's value as a key stepping stone between the coastal dune swale and estuary wetlands to the south, and Mata Kopae/St Anne's Lagoon and the Kaikoura wetlands to the north.

Acoustic Recording

The recordings made during five-minute counts can be used to validate the standard five-minute bird counts and provide a record of bird call 'atmospheres' for comparison between monitoring periods. The acoustic data might also be useful to monitor long-term trends in bird counts when suitable software is available to accurately recognise species calls.

RECOMMENDATIONS

- The decline in mean counts of birds between 2005 and 2017 is most probably caused by mammalian predators, therefore multi-species predator control management should be implemented to arrest these declines. Regular monitoring of mammalian predator and browser numbers should also be carried out.
- If best practice predator control is undertaken, the area might become suitable for reintroductions of species such as fernbird and robin. Similarly, populations of tomtit and brown creeper could be enhanced by reintroductions.
- The former valley floor wetlands should be restored to their former extent to increase the area of habitat for wetland birds. Extending shrublands and *Carex* sedgelands will provide suitable fernbird habitat, and increasing the area of shallow water edges with raupo and *Carex secta* will provide extra habitat for crake and bittern.

- The most cost-effective way to restore former wetland area is to block the main valley drain in several areas above Kate Pond. This will flood more of the valley floor, but unfortunately also make access tracks wetter. Mitigation options include re-routing tracks along the base of the hillside or infilling the lowest sections of the existing tracks to form low causeways. These causeways would require culverts to maintain water sheet flow and prevent excessive diversion and channelization of water. Other options for increasing wetland bird habitat include constructing another weir or dam, and planting raupo around the shores of the top Ella Pond. There is one very small patch of raupo here, but it is too small to provide crake or fernbird habitat and is dominated by a nesting black swan.
- Detailed morphological assessments of 'grey/mallard' ducks should be carried out in future wetland surveys to determine whether purebred grey ducks are present.
- Playback surveys for at risk and threatened wetland birds including spotless crake, marsh crake, bittern and fernbird should be continued. The playback points and methods established this year should be used for consistency, although additional points could be established if the habitat expands.
- Increasing the use of acoustic recorders for sampling forest birds should be considered, as this is likely to become a standard method to monitor NZ's forest birds in the future.
- There should be ongoing scrutiny of density estimates obtained from distance sampling analyses to improve the quality of the data collected and ensure that the method is effective. Future distance counts should entail daily calibration of distance estimates, using a rangefinder.

Conclusion

The bird monitoring carried out at the CMA provides good baseline data for evaluating long-term bird population trends in the area. However, some caution is required when interpreting trends because counts can be affected by a number of factors such as observers' performance, variation in the timing of breeding seasons, weather conditions, and predator abundance.

A more focused survey of wetland species during 2017 resulted in at least one new species being recorded: the spotless crake, listed by DOC as 'At Risk: Declining' (Robertson et al. 2017). Further surveys are required to confirm whether marsh crake are present and whether ducks seen in the area are critically threatened grey duck or the almost indistinguishable mallard-grey duck hybrids. Maintaining wetland habitat is crucial for the protection of species currently occupying them, while the restoration of former wetland areas would offer new opportunities for endangered species such as bittern to colonise.

Occasional observation of species such as kereru, tomtit and brown creeper in the area suggests that these and other species will colonize the area successfully once the quality and extent of forest and scrub habitat improves. However, the significant decline in bird numbers, especially bellbird numbers, between 2005 and 2017 cannot be easily explained. Further monitoring will be required to see whether the observed trend is part of a continuing decline or merely a cyclic fluctuation in numbers. If the decline in counts reflects an actual decline in population densities, introduced mammalian predators are likely to be the primary cause. Predator control would be essential before considering relocations of birds such as tomtit, robin or fernbird to the CMA.

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APPENDIX

Annotated bird list grouped according to habitat (2005-2017)

Table A1. Forest and scrub birds, including some species that are also found in open habitat. (NT= Not Threatened)

Common Name	Latin Name	Gen. Status	Threat status	Abundance
Kereru	*Hemiphaga novaeseelandiae*	Endemic	NT	Occasional in 2017: one record previous monitors
Shining cuckoo	*Chrysococcyx lucidus lucidus*	Native	NT	Occasional all years
Kingfisher	*Todiramphus sanctus vagans*	Native	NT	Not recorded in 2017. Occasional 2005-2009
Grey warbler	*Gerygone igata*	Endemic	NT	Common all years
Brown creeper	*Mohoua novaeseelandiae*	Endemic	NT	Not recorded in 2017: one record in 2009
South Island fantail	*Rhipidura fuliginosa fuliginosa*	Native	NT	Frequent all years
South Island tomtit	*Petroica macrocephala macrocephala*	Endemic	NT	rare records (one individual: 2007 and 2017 only)
Silvereye	*Zosterops lateralis lateralis*	Native	NT	Common all years
Bellbird	*Anthornis melanura melanura*	Endemic	NT	Common all years
California quail	*Callipepla californica*	Introduced	NT	Rare-occasional in 2017. Locally frequent in other years
Dunnock	*Prunella modularis*	Introduced	NT	Common all years
Chaffinch	*Fringilla coelebs*	Introduced	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 carduelis*	Introduced	NT	Common
Redpoll	*Carduelis flammea*	Introduced	NT	Common
Starling	*Sturnus vulgaris*	Introduced	NT	Local, infrequent
Australian magpie	*Gymnorhina tibicen*	Introduced	NT	Frequent

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
White-faced heron	*Ardea novaehollandiae*	Native	NT	Occasional
Spur-winged plover	*Vanellus miles navaehollandiae*	Native	NT	Occasional
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, etc
Black swan	*Cygnus atratus*	Introduced/self-introduced	NT	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-mallard hybrid	*Anas platyrhynchos*	Introduced	NT	Common, breeding
Grey teal	*Anas gracilis*	Native	NT	Variably frequent
New Zealand scaup	*Aythya novaeseelandiae*	Endemic	NT	Common each year
Australasian Shoveler	*Anas rhynchotis*	Native	NT	Common
Pied stilt	*Himantopus himantopus leucocephalus*	Native	NT	A few each year
Spotless crake	*Porzana t. tabuensis*	Native	At risk: declining	At least seven responded to playback at Kate Valley wetland in 2017. One sighting

Table A5. Unconfirmed species.

Common Name	Latin Name	Gen. Status	Threat status	Abundance, etc
Grey duck	*Anas superciliosa*	Endemic	Nationally Critical	Very likely grey x mallard hybrid as very difficult to distinguish morphologically
Marsh crake	*Porzana pusilla affinis*	Native	At risk: declining	Two calls heard, most likely spotted crake
Tui	*Prosthemadera n.novaeseelandiae*	Endemic	NT	One presumed heard at Transect 8, 2005