Bird Counts

Cape to City Project, Hawkes Bay

Photo Credit: Dick Porter

A report prepared for the
Cape to City Project Management Team

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Abstract

This is the second report on bird counts in the Cape to City footprint and its immediate surrounds. It presents the results of counts collected in 2017 and 2018 from the three areas relevant to the Cape to City programme: *Cape Sanctuary* on the Cape Kidnappers headland; the 26,000 ha Cape to City footprint on the southern boundary of *Cape Sanctuary*; and the 20,000 ha Cape to City non-treatment area, to the south and west of the footprint. The report examines whether treatment effects resulting from the Cape to City management programme are beginning to emerge in the footprint area. It also assesses the extent to which bird abundance varies in the three counting areas over time, and whether the current sampling regime is of sufficient intensity to achieve its design brief and detect abundance changes of ≥ 20%.

The abundance of a surprisingly large number of native and introduced species changed from 2015/16 to 2017/18. Some of the changes were generic in that they were evident in all three counting areas, while others were specific to particular counting areas, or particular habitat types. Amongst native species, silvereyes increased in all counting areas, while shinning cuckoo and kingfisher decreased. Amongst introduced species, magpies increased but greenfinch decreased. The causes of these changes are not known, nor do they appear to be signaling environmental changes that might otherwise escape notice.

Within the footprint, robins, tui, bellbirds, fantail, grey warbler and rifleman increased, all apparently in response to the Cape to City management programme. The growth and expansion of the robin population was particularly spectacular, resulting from the combined influences of predator control, natural dispersal out of *Cape Sanctuary*, and a successful translocation programme, which sourced robins from the wider Hawkes Bay region and released them in forests at the southern end of the footprint. Conversely, tomtits, whiteheads, and kakariki did not increase in the footprint - though logging in 2017 and 2018 probably extinguished the beginnings of tomtit and whitehead establishment in pine forests at the northern end.

Predator control in the footprint did not influence the abundance of desirable species such as pheasants and Californian quail, nor the abundance of undesirable ones, such as pests of vineyards and cereal crops (starlings and various finches). It also did not influence the abundance of rabbits, which were recorded incidentally during the counts of farmland birds.

Extensive logging in the counting areas in 2018 removed woody habitat from places where there was already little of it, the steeping stones that linked *Cape Sanctuary* to the footprint, and a large number of counting sites used for both the baseline (15/16) and follow-up (17/18) counts. These habitat losses now make it more difficult for species of *Cape Sanctuary* origin to move to the footprint and find living spaces within it. The losses will also reduce the integrity and statistical power of the sampling programme if equivalent counting sites cannot be established elsewhere.

The next round of counts is planned for 3-5 years time. A pause of this duration will give slow-breeding species sufficient time to respond to predator control in the footprint, if they are to do so. The extent to which the general lack of woody vegetation in the footprint may mute the response of various native species to predator control is discussed.

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Introduction

This is the second report on bird counts in the Cape to City footprint and its immediate surrounds. It follows on from McLennan (2017) which described the results of 'baseline' counts in the first two years of the project, from late 2015 to the end of 2016.

The 'baseline' counts were undertaken in three areas: in the 26,000 ha Cape to City footprint; in the 2600 ha *Cape Sanctuary* on the Cape Kidnappers Peninsula at the northern end of the footprint; and in a 20,000 ha non-treatment area on the western side of the Cape to City footprint. The location and boundaries of these three areas are shown in McLennan (2017).

The baseline counts showed that:

- native bird abundance and diversity was generally higher in *Cape Sanctuary* than the Cape to City footprint and non-treatment area, an expected result given *Cape Sanctuary's* long history of intensive predator control and species translocation programmes (McLennan, 2016);
- native birds were generally most plentiful in indigenous forests and shrublands, while introduced birds were generally most plentiful in exotic *Pinus radiata* forests, a pattern evident in all three counting areas; and
- bird abundance was virtually identical in the Cape to City footprint and Non-treatment area when differences attributable to forest type were accounted for. In other words, it showed that the non-treatment area was a useful 'experimental control' for the footprint, even though it is further from *Cape Sanctuary* (and the native species dispersing out of it) than the footprint itself.

This report updates the original one. It presents the results of counts in native and exotic forests after: 1) 18 months of extensive top-predator control and localised rat control in the northern half of the Cape to City footprint, and 2) the completion of a translocation programme aimed at re-establishing robins and tomtits in native forest at the southern end of the footprint (McLennan and Nakagawa, 2018). It specifically examines variation in bird abundance in each of the three project areas over time, and evaluates whether treatment effects resulting from the Cape to City management programme are beginning to emerge in the footprint area.

The Cape to City bird counting programme was originally designed to detect a 20% difference in bird abundance between the three counting areas, and between different time periods within counting areas. The analyses of Dawson and Bull (1975) showed that more counts are required to detect a 20% difference for rare species than abundant ones. The species of special interest for the Cape to City programme are those that may respond to top-predator control. They include native species with high biodiversity values, introduced waterfowl and gamebirds with high recreational values, and pest species that may later become more troublesome if they became more numerous or widespread.

The report presents the results of power analyses (Snedecor and Cochran, 1967) on the species of interest, to check whether the sampling programme will - as intended - have a high probability of detecting a ≥ 20% difference in their abundance, should such a change eventuate over the next few years. The intention now is to suspend counting for 3-5 years to give the species of interest sufficient time to respond to predator control in the footprint area. A pause of this duration is appropriate given that some of the potential respondents (eg kaka) may breed only once or twice in a 5-year period.

A difficulty the sampling programme is already encountering is the loss of counting sites, caused by the harvesting of pine plantations. Larger losses are expected over the next 5 years, fueled by the current spike in timber prices and the harvesting of trees at an earlier than usual stage of the rotation cycle. The report quantifies the probable magnitude of these losses, their potential effects on sample size and statistical power in 5 years time, and the levels of site replacement that may be required in the next few years to maintain the integrity of the sampling programme.

Methods

1.0 Counting methods and location of transects.

The methods used to count birds in the three project areas and the locations of count sites were described by McLennan (2017). This information is not repeated here, other than to restate that the 5-minute technique of Dawson and Bull (1976) was used to count forest birds; and a road-transect technique was used to count game birds and pest species in farmland. The same counting sites were used for both the baseline (2015/16) and follow-up (2017/18) counts.

2.0 Time periods and sample size

The analyses in McLennan (2017) of bird abundance in forested habitats were based on 739 5-minute counts collected in spring 2015 and the first 8 months of 2016. The analyses in this report are based on 2,258 counts, being the original sample (739) and the counts (1519) collected subsequently (Table 1).

The analyses in this report compare bird abundance in the three counting areas in two time periods: before (Period 1) and after (Period 2) the onset of top-predator control in the footprint area. The sample size was 1281 counts for Period 1 and 977 counts for Period 2 (Table 1). In terms of calendar years, Period 1 comprised 2015 & 2016, and Period 2 2017 & 2018.

It is important to note that the 'roll out' of the top-predator control programme in the footprint started at the northern end and took about 24 months to complete. The counts in Period 2 from the footprint therefore comprise a mix of treatment (with top predator control) and non-treatment samples (no top-predator control) depending on when and where they were collected. The analyses in the report recognise these two types of counts and distinguish between them when appropriate.

Table 1: Number of 5-minute counts by year and counting area. The top-predator control programmes in each counting area were as follows: *Cape Sanctuary* - intensive control in all four years: non-treatment area - no control in all four years: footprint area - no control in first two years, expanding predator control thereafter, with complete coverage of the footprint achieved in late 2018.

Counting Area	2015	2016	2017	2018
Cape Sanctuary	95	170	248	96
Cape to City footprint	130	628	357	146
Non-treatment Area	100	158	110	20

3.0 Statistical analyses

Differences between means on untransformed data were tested with either ANOVA or Students T-test for independent samples, using the programme Systat®.

4.0 Power analyses

The following values were used in the power analyses:

- Effect size = 20%
- Alpha (the significance level of the test) = 0.05
- Beta (the probability of accepting a false negative) = 10%
- Power = 1 - Beta (i.e 90% in this case)
- Standard deviation = as measured in the counts

The power analyses therefore identified the sample size required to detect a significant result 90% of the time (and a non-significant result 10% of the time) with a real effect size of ≥ 20%.

Results

1) Variation in bird abundance in the three counting areas over time, as measured by 5-minute counts in forests

1.1 Native birds

Native bird abundance in each of the three counting areas (*Cape Sanctuary*, Cape to City footprint and non-treatment area) is shown in Tables 2a, 2b and 2c, respectively. Within each counting area, the counts are analysed in relation to time (Period 1 and Period 2). In two of the counting areas (Cape to City footprint and non-treatment area) the counts are also analysed in relation to habitat type (pine forest and indigenous forest). This second tier of analysis adds an unwelcome layer of complexity, but is necessary to prevent 'unintended' habitat effects confounding the comparisons between time periods. The habitat effects were caused by the loss of some of the counting stations in pine forests in the footprint and non-treatment area in Period 2. This decreased the proportion of counts in pine forests in Period 2 in those areas (see sample sizes in Tables 2b and 2c) and thereby changed the apparent mean abundance of some species in the pooled sample from those areas. The habitat analysis was not required in *Cape Sanctuary* because the sampling regime there was identical for both time periods.

1.1.1 Generic changes

The results in Tables 2a, 2b, and 2c, show that the abundance of some native species changed little over time, while others varied substantially. Some of the changes were generic, in that they were evident in all three counting areas, while others were specific to a particular counting area, or a habitat type within a counting area.

Generic changes from Period 1 to Period 2 were recorded for kingfisher (decline) shinning cuckoo (decline) and silvereye (increase). These generic changes appeared to be driven entirely by natural and/or chance processes that had nothing to do with changes in predator abundance or predator management. Silvereye changed the most, doubling or tripling in abundance in all counting areas from Period 1 to Period 2. This increase may signal the beginnings of a wider recovery from a probable disease event that reduced silvereye populations nationwide in the first decade of this century - though increases of a similar magnitude have not yet been recorded in other parts of New Zealand (MacLeod et.al., 2018).

The declines of both shinning cuckoo and kingfisher both appear to be real and of unknown cause. The decline of shinning cuckoo probably also extended beyond the counting areas, and appeared to result from a reduction in the number of cuckoos arriving in Hawkes Bay (and possibly New Zealand) in the spring of 2017. The abundance of the cuckoo's obligate host - grey warbler - did not change much from Period 1 to Period 2 in the counting areas, suggesting that host availability had no part in the cuckoo's decline. The decline of kingfisher was probably local, since similar declines have not been reported from other parts of Hawkes Bay, or other parts of New Zealand.

1.1.2 Specific changes

Specific changes in abundance, limited to certain areas or habitats, were much more common than generic changes. In *Cape Sanctuary*, there were 5 such changes from Period 1 to Period 2, some with no obvious explanation or pattern (Table 2a). Amongst small forest insectivores, tomtits declined from Period 1 to Period 2, but robins and grey warblers increased. Amongst the parrots, kakariki increased but kaka declined; and amongst the honeyeaters, bellbirds were stable but tui declined.

Specific changes in abundance were also evident in the footprint (8 examples amongst native species), with most of the changes apparently being driven by the Cape to City management programme. In the case of robins, the predator control programme (including targeted rat control) created safe places for the birds to inhabit at both ends of the footprint, while the translocation programme (McLennan and Ngakawa, 2017) facilitated their establishment in some of those safe places. Natural outflow from *Cape Sanctuary* also contributed to population establishment and growth at the northern end of the footprint.

The increases in fantail, tui and bellbird abundance in pine forests in the footprint (Table 2b) were evident only in two sites that were subjected to near continuous rat control and top predator control - suggesting again that they were responses to this management rather than to natural processes. Both of the sites were within a few hundred metres of *Cape Sanctuary*, well within the daily commuting range of some of its inhabitants, and close enough to it to become an extension of the sanctuary itself. The two sites were dominated by exotic pines, but they also included ribbons of native vegetation of varying size, some with nectar (eg. kowhai) and fruit producing species (eg. karaka). Their botanic diversity explains why predator control in these sites appeared to generate population responses from at least two species (tui and bellbird) that are not normally year-round inhabitants of pine forests. There were no equivalent increases in bird abundance in a third counting site in pine forest that received no rat control, and almost no top predator control, in Period 2. This site was in the middle of the footprint, about 5 km from *Cape Sanctuary.*

There were only two significant specific changes in the non-treatment area from Period 1 to Period 2 and both were relatively small: tui numbers declined in pine forest, and kereru declined in native forest (Table 2c).

Table 2a: Native bird abundance in *Cape Sanctuary* in Period 1 (2015/2016) and Period 2 (2017/2018). Numbers are mean number of individuals seen and heard per 5-minute count ± 1 standard deviation.

Species	N	Period 1	N	Period 2	T-test and significance
Robin	263	0.37 ± 0.76	344	0.53 ± 0.74	t = 2.6, p <0.023
Tomtit	263	0.31 ± 0.59	344	0.16 ± 0.41	t = 3.6, p < 0.001
Whitehead	263	0.41 ± 1.0	344	0.36 ± 0.97	t = 0.61, ns
Grey Warbler	263	1.22 ± 1.23	344	1.48 ± 1.22	t = 2.62, p < 0.001
Fantail	263	0.38 ± 0.71	344	0.43± 0.70	t = 0.75, ns
Silvereye	263	0.55 ± 1.14	344	1.69 ± 2.25	t = 8.1, p <0.000
Bellbird	263	2.68 ± 2.26	344	2.83 ± 2.32	t = 0.78, ns
Tui	263	2.15 ± 1.97	344	1.24 ± 1.56	t = 6.2, p <0.000
Kereru	263	0.17 ± 0.51	344	0.13 ± 0.42	t = 0.94, ns
Kakariki	263	0.29 ± 0.71	344	0.72 ± 1.13	t = 5.7, p <0.000
Kaka	263	0.14 ± 0.49	344	0.07 ± 0.32	t = 2.0, p <0.05
Kingfisher	263	0.39 ± 0.67	344	0.08 ± 0.32	t = 6.7, p <0.000
Shinning cuckoo	263	0.19 ± 0.39	344	0.0 ± 0.0	F = 31 p < 0.000

Table 2b: Native bird abundance in the Cape to City footprint in Period 1 (2015/2016) and Period 2 (2017/2018). Conventions as for Table 2a.

Species	Habitat	N	Period 1	N	Period 2	T-test and significance
Robin	Pine	530	0.02 ± 0.17	275	0.14 ± 0.43	t = 4.5, p <0.000
	Native	228	0.11 ± 0.40	228	0.53 ± 0.80	t = 7.1, p <0.000
Tomtit	Pine	530	0.006 ± 0.08	275	0.004 ± 0.06	t = 0.6, ns
	Native	228	0 ± 0	228	0 ± 0	t = 0.0, ns
Whitehead	Pine	530	0.004 ± 0.06	275	0 ± 0	t = 0.3, ns
	Native	228	0 ± 0	228	0 ± 0	t = 0.0, ns
Grey Warbler	Pine	530	0.96 ± 1.36	275	2.32 ± 1.36	t = 14.0, p <0.000
	Native	228	2.24 ± 1.62	228	1.73 ± 1.42	t = 3.6, p <0.000
Fantail	Pine	530	0.48± 0.83	275	0.98 ± 1.07	t = 7.0, p <0.000
	Native	228	0.48 ± 0.77	228	0.50 ± 0.73	t = 0.3, ns
Silvereye	Pine	530	0.39 ± 1.06	275	1.64 ± 1.82	t = 10.5, p <0.000
	Native	228	1.69 ± 2.06	228	1.83 ± 1.82	t = 0.7, ns
Bellbird	Pine	530	0.14 ± 0.56	275	0.36 ± 0.69	t = 4.5, p <0.000
	Native	228	0.43 ± 0.77	228	0.45 ± 0.88	t = 0.22, ns
Tui	Pine	530	0.64 ± 1.31	275	1.66 ± 1.99	t = 7.7, p <0.000
	Native	228	3.57 ± 1.76	228	3.20 ± 1.98	t = 2.0, p <0.04
Kereru	Pine	530	0.07 ± 0.44	275	0.13 ± 1.99	t = 1.65, ns
	Native	228	1.32 ± 1.10	228	1.04 ± 1.27	t = 0.8, ns
Kingfisher	Pine	530	0.19 ± 0.47	275	0.12 ± 0.37	t = 2.4, p <0.014
	Native	228	0.25 ± 0.57	228	0.17 ± 0.50	t = 1.6, ns
Shinning cuckoo	Pine	530	0.04 ± 0.24	275	0.0 ± 0.0	t = 0.2, ns
	Native	228	0.11 ± 0.33	228	0.0 ± 0.0	t = 0.2, ns

Table 2c: Native bird abundance in the Cape to City non-treatment area in Period 1 (2015/2016) and Period 2 (2017/2018). Conventions as for Table 2a.

Species	Habitat	N	Period 1	N	Period 2	T-test and significance
Robin	Pine	156	0 ± 0	80	0 ± 0	t =0, ns
	Native	60	0 ± 0	50	0 ± 0	t = 0, ns
Tomtit	Pine	156	0 ± 0	80	0 ± 0	t = 0.0, ns
	Native	60	0 ± 0	50	0 ± 0	t = 0.0, ns
Whitehead	Pine	156	0 ± 0	80	0 ± 0	t = 0.0, ns
	Native	60	0 ± 0	50	0 ± 0	t = 0.0, ns
Grey Warbler	Pine	156	1.72 ± 1.26	80	1.70 ± 1.29	t = 0.12, ns
	Native	60	2.17 ± 1.58	50	1.92 ± 1.32	t = 0.89, ns
Fantail	Pine	156	0.50± 0.78	80	0.59 ± 0.69	t = 0.88, ns
	Native	60	1.50 ± 1.27	50	1.30 ± 1.25	t = 0.83, ns
Silvereye	Pine	156	0.20 ± 0.61	80	0.86 ± 1.82	t = 3.76, p <0.000
	Native	60	1.00 ± 1.75	50	1.48 ± 1.75	t = 1.42, ns
Bellbird	Pine	156	0.03 ± 0.16	80	0.05 ± 0.27	t = 0.75, ns
	Native	60	0.12 ± 0.37	50	0.0 ± 0.0	t = 0.10, ns
Tui	Pine	156	0.27 ± 0.54	80	0.11 ± 0.36	t = 2.73, p <0.007
	Native	60	3.82 ± 1.87	50	3.28 ± 1.76	t = 1.54, ns
Kereru	Pine	156	0.004 ± 0.07	80	0.006 ± 0.08	t = 0.1, ns
	Native	60	1.45± 1.70	50	0.78 ± 1.09	t = 2.49, p < 0.014
Kingfisher	Pine	156	0.13 ± 0.42	80	0.20 ± 0.46	t = 1.19, ns
	Native	60	0.75 ± 0.86	50	0.32 ± 0.55	t = 3.18, p < 0.02
Shinning cuckoo	Pine	156	0.16 ± 0.55	80	0.0 ± 0.0	t = 0.1, ns
	Native	60	0.02 ± 0.16	50	0.0 ± 0.0	t = 0.1, ns

Overall, the footprint had about the same proportion of species abundance changes as *Cape Sanctuary*; and both of these areas had more changes than the non-treatment Area (Table 3). Thus all three counting areas experienced some variation in bird abundance over time, but the two areas with restoration management experienced more. This result is not surprising: in managed areas, variation is generated by two processes (management and natural) whereas in unmanaged areas it is generated by just one process (natural). The analyses show that the management programme is beginning to enhance native bird abundance in the footprint, a primary goal of the Cape to City programme. Robins are leading the charge.

Table 3: Summary of abundance changes of native birds in the three counting areas from Period 1 to Period 2. Red indicates a decline, green an increase, and white or grey, no change.

Species	Cape Sanctuary	Cape to City Footprint	Non treatment
Robin	Overall increase in sanctuary	Overall increase in footprint, evident in both pine and native forest	Not present
Tomtit	Overall Decline	No change but extremely scarce	Not present
Whitehead	No change	No change but no longer detected in footprint	Not present
Grey warbler	Overall increase in sanctuary	Overall increase in footprint, resulting from increase in pine forest at northern end of footprint	No change
Fantail	No change	Overall increase in footprint, resulting from increase in pine forest at northern end of footprint	No change
Silvereye	Overall increase in sanctuary	Overall increase in footprint, resulting from increase in pine forest at northern end of footprint	Overall increase throughout Non-treatment area, evident in both forest types
Rifleman	Present but not detected in counts	Overall increase in footprint, but distribution restricted to native forest at southern end of footprint	Not present
Bellbird	No change overall	Overall increase in footprint, resulting from increase in pine forest at northern end of footprint	No change
Tui	Overall decline	Overall increase in footprint, resulting from increase in pine forest at northern end of footprint	No change
Kereru	No change	No change	No change
Kakariki	Overall increase in sanctuary	Infrequent visitor, not detected in counts	Not present
Kaka	Overall decline	Very infrequent visitor, not detected in counts	Not present
Kingfisher	Overall decline	Overall decline	No change
Shinning cuckoo	Overall decline	Overall decline	Overall decline

1.2 Introduced birds

The abundance of introduced birds in the three counting areas in Periods 1 and 2 is shown in Tables 4a (*Cape Sanctuary*) 4b (Cape to City footprint) and 4c (non-treatment area). Hedge sparrow, redpoll, yellow hammer, skylark and rosella are not shown in the tables because they were detected very infrequently. Mynas were not detected at all, but are shown in the tables because some readers may look for them. Mynas are of special interest because they are a noted pest that may well expand their distribution in coming years in response to climate change.

The introduced species were similar to the native ones in that they also exhibited a large number of abundance changes from Period 1 to Period 2, some generic and others limited to particular counting areas or habitats. However, for the introduced species, most (if not all) changes appeared to result from natural causes rather than the C2C management programme. This conclusion follows because the abundance changes evident in the footprint were also seen in places not receiving top-predator control (see below).

1.2.1 Generic changes

Three introduced species exhibited generic abundance changes across all three counting areas: greenfinch (decline), house sparrow (decline) and magpie (increase). The decline of greenfinch and the increase in magpie abundance were both pronounced.

1.2.2 Specific changes

In *Cape Sanctuary*, introduced birds generally decreased from Period 1 to Period 2, with the single exception of magpie. This included the gamebirds, though the counts in the sanctuary did not sample the places where quail are most numerous (rough farmland and road verges). The pheasant population in *Cape Sanctuary* is augmented occasionally by releases of captive-raised birds, and there were fewer releases there in Period 2 than Period 1.

Within the Cape to City footprint, chaffinches increased in both native and pine forests, and starlings increased in native forests (Table 3b). Neither of these increases resulted from predator control, because similar changes were also evident in the non-treatment area (Table 3c). Starling abundance in native forests seems to be linked to the availability of nest cavities, a resource that probably varies in abundance from year to year as trees die and limbs rot and fall.

Table 4a: Abundance of introduced birds in *Cape Sanctuary* in Period 1 (2015/2016) and Period 2 (2017/2018). Conventions as for Table 2a.

Species	N	Period 1	N	Period 2	T-test and significance
Chaffinch	263	1.85 ± 1.77	344	1.67 ± 1.61	F = 1.9, ns
Greenfinch	263	1.21 ± 1.73	344	0.04 ± 0.25	F= 153, P < 0.000
Goldfinch	263	0.41 ± 0.90	344	0.48 ± 0.94	F = 1.1, ns
House sparrow	263	0.27 ± 1.04	344	0.12 ± 0.53	F = 3.4, P < 0.001
Blackbird	263	0.46± 0.80	344	0.22 ± 0.49	F = 20.4, P < 0.000
Thrush	263	0.05 ± 0.24	344	0.003 ± 0.054	F = 10.0, P < 0.01
Magpie	263	0.8 ± 1.06	344	1.25± 1.33	F = 20.7, P <0.000
Starling	263	0.06 ± 0.45	344	0.041 ± 0.23	F = 0.30, ns
Myna	263	0 ± 0	344	0 ± 0	F = 0, ns
Californian Quail	263	0.01 ± 0.10	344	0 ± 0	F = 3.9 P < 0.05
Pheasant	263	0.103 ± 0.32	344	0.02 ± 0.61	F= 17.4, P < 0.001

To summarise (Table 5) the counts indicate the Cape to City management programme is not affecting the abundance of any introduced species in the footprint, for better (gamebirds) or for worse (pest species). This finding was expected, given that the populations of most introduced birds In New Zealand appear to be limited by factors other than mammalian predators. There is perhaps a slight indication that blackbirds and thrushes are declining in *Cape Sanctuary* as native ground-feeding species increase - but it is too early to tell whether the trend is real or not.

Table 4b: Abundance of introduced birds in the Cape to City footprint in Period 1 (2015/2016) and Period 2 (2017/2018). Conventions as for Table 2a.

Species	Habitat	N	Period 1	N	Period 2	T-test or Anova and significance
Chaffinch	Pine	530	1.82 ± 2.19	275	2.72 ± 2.16	t = 5.5, p <0.000
	Native	228	0.78 ± 1.11	228	1.04 ± 1.29	t = 2.48, p <0.05
Greenfinch	Pine	530	1.22 ± 1.86	275	0.32 ± 0.85	t = 9.4, P < 0.000
	Native	228	0.39 ± 0.77	228	0.22 ± 1.47	t = 3.58, P < 0.00
Goldfinch	Pine	530	0.48 ± 1.03	275	0.54 ± 0.94	t = 0.78, ns
	Native	228	0.26 ± 0.67	228	0.46 ± 0.99	t = 0.84, ns
House sparrow	Pine	530	0.27 ± 1.04	275	0.04 ± 2.81	t = 4.9, P <0.000
	Native	228	0.05± 0.30	228	0 ± 0	F = 5.6, P <0.05
Blackbird	Pine	530	0.61± 1.25	275	0.67 ± 0.97	t = 0.7, ns
	Native	228	1.22 ± 1.44	228	1.09 ± 1.31	t = 0.3, ns
Thrush	Pine	530	0.04 ± 0.26	275	0.04 ± 0.24	t = 0.09, ns
	Native	228	0.15 ± 0.54	228	0.08 ± 0.34	t = 1.65, ns
Magpie	Pine	530	0.87 ± 1.39	275	2.03 ± 1.69	t = 9.8, P <0.000
	Native	228	0.89 ± 1.13	228	1.24 ± 1.32	t = 3.08, P < 0.002
Starling	Pine	530	0.12 ± 0.49	275	0.06 ± 0.33	t = 2.09, P <0.05
	Native	228	0.14 ± 0.53	228	0.42 ± 0.91	t = 3.9, P <0.000
Myna	Pine	530	0 ± 0	275	0 ± 0	t = 0, ns
	Native	228	0 ± 0	228	0 ± 0	t = 0, ns
Californian Quail	Pine	530	0.004 ± 0.06	275	0.02 ± 0.24	t = 0.7, ns
	Native	228	0.004 ± 0.67	228	0 ± 0	t = 1.0, ns
Pheasant	Pine	530	0.08 ± 0.36	275	0.04 ± 0.23	t = 1.79, ns
	Native	228	0 ± 0	228	0.01 ± 0.09	F = 2.0 , ns

Table 4c: Abundance of introduced birds in the non-treatment Area in Period 1 (2015/2016) and Period 2 (2017/2018). Conventions as for Table 2a.

Species	Habitat	N	Period 1	N	Period 2	T-test and significance
Chaffinch	**Pine**	198	**3.38 ± 2.05**	80	**4.15 ± 2.10**	**t = 2.8, p <0.006**
	Native	60	**1.93 ± 1.94**	50	**1.66 ± 1.29**	**t = 0.88, ns**
Greenfinch	**Pine**	198	**1.63 ± 1.97**	80	**0.76 ± 1.66**	**t = 3.74, P < 0.000**
	Native	60	**0.18 ± 0.77**	50	**0.10 ± 0.42**	**t = 0.72, ns**
Goldfinch	**Pine**	198	**0.62 ± 1.13**	80	**0.77 ± 1.17**	**t = 1.0, ns**
	Native	60	**0.58 ± 1.15**	50	**0.28 ± 0.61**	**t = 3.76, ns**
House sparrow	**Pine**	198	**0.37 ± 2.21**	80	**0.25 ± 2.24**	**t = 0.4, ns**
	Native	60	**0.40 ± 1.17**	50	**0.04 ± 0.28**	**t = 2.31, P < 0.02**
Blackbird	**Pine**	198	**2.12 ± 1.84**	80	**2.55 ± 1.94**	**t = 1.67, ns**
	Native	60	**1.22 ± 1.46**	50	**0.78 ± 0.95**	**t = 1.89, ns**
Thrush	**Pine**	198	**0.21 ± 0.57**	80	**0.06 ± 0.291**	**t = 2.77, P < 0.006**
	Native	60	**0.03 ± 0.18**	50	**0.24 ± 0.59**	**t = 2.38, P <0.02**
Magpie	**Pine**	198	**0.82 ± 1.25**	80	**1.41 ± 1.34**	**t = 3.4, P <0.001**
	Native	60	**0.85 ± 1.27**	50	**1.30 ± 1.15**	**t = 1.94, ns**
Starling	**Pine**	198	**0.03 ± 0.24**	80	**0 ± 0**	**t = 0.2, ns**
	Native	60	**1.12 ± 1.50**	50	**2.38 ± 1.60**	**t = 4.24, P < 0.000**
Myna	**Pine**	198	**0 ± 0**	80	**0 ± 0**	**t = 0, ns**
	Native	60	**0 ± 0**	50	**0 ± 0**	**t = 0, ns**
Californian Quail	**Pine**	198	**0.005 ± 0.07**	80	**0 ± 0**	**t = 0.2, ns**
	Native	60	**0 ± 0**	50	**0 ± 0**	**t = 0, ns**
Pheasant	**Pine**	198	**0.005 ± 0.07**	80	**0 ± 0**	**t = 0.2 ,ns**
	Native	60	**0 ± 0**	50	**0 ± 0**	**t = 0, ns**

Table 5: Summary of changes for introduced birds in the three counting areas from Period 1 to Period 2.

Species	Cape Sanctuary	Cape to City Footprint	Non treatment
Chaffinch	No change	Overall increase in footprint, evident in both pine and native forest	Increase in pine forest habitats
Greenfinch	Overall Decline	Overall decline	Overall decline
Goldfinch	No change	No change	No change
House sparrow	Overall decline	Overall decline	No change
Blackbird	Overall decline	No change	No change
Thrush	Overall decline	No change	No change
Magpie	Overall increase	Overall increase	Overall increase
Starling	No change overall	Overall increase	Overall increase
Myna	No change, but absent	No change, but absent	No change, but absent
Californian Quail	Slight decline but seldom detected	No change	No change
Pheasant	Overall decline	Overall decline but seldom detected	No change

2) Variation in bird and mammal abundance in the Cape to City footprint and non-treatment area, as measured by road counts.

The counts along country roads were designed to measure the abundance of selected native and introduced birds that typically inhabit open paddocks (McLennan, 2017). Such species required a tailored sampling programme because the 5-minute counts in woodlands either missed them altogether, or failed to detect them often enough to provide useful measures of their abundance. The road surveys focused on large species that were easily seen - various puddle ducks (mallard, grey duck and grey teal), paradise shelducks, game birds, various pest species (eg. magpies) and feral populations of domestic species (geese and turkeys) that are regarded as pests by some people, and as assets by others. The counts also focused on mammals of interest to the Cape to City programme: the top predators themselves, and some of their prey species (rabbits and hares) which could potentially increase in abundance following top predator control.

With two exceptions, the abundance of farmland birds did not change from Period 1 to Period 2 in either the footprint (Table 6a) or the non-treatment area (Table 6b). The two exceptions were magpies and harriers, which increased in both counting areas from Period 1 to Period 2. The increase in magpies was particularly large, mirroring the trend in the 5-minute counts. The results of the road counts and five-minute counts were also similar for game birds, with no evidence of an early response to top-predator control in the footprint.

The results of Tables 6a and 6b, when analysed by location, also show that the farmland inhabitants were spread remarkably evenly across the two counting areas. Only one species - pukeko - was more abundant in the footprint than the non-treatment area, the result of a localised population increase in orcharding areas at the northern end of the footprint. All other species were equally numerous in both areas.

Table 6a: Abundance of birds in farmland in the Cape to City footprint in Period 1 and Period 2. The counts are of individuals seen on 8 sections of road, totaling 100 km in the footprint. The 8 sections of road were counted 6 times in Period 1 and 5 times in Period 2.

Species	N	Period 1	N	Period 2	F-test and significance
Magpie	48	4.2 ± 3.9	40	9.0 ± 5.7	F = 21.2, P < 0.000
Harrier	48	0.33 ± 0.63	40	0.75 ± 0.90	F= 6.5, P < 0.005
Turkey	48	3.1 ± 5.9	40	4.6 ± 9.4	F = 0.71, ns
Feral Goose	48	0.58 ± 3.17	40	1.5 ± 5.5	F = 1.04, ns
Pheasant	48	0.56 ± 1.58	40	0.47 ± 1.0	F = 0.09, ns
Californian Quail	48	2.2 ± 6.0	40	1.40 ± 4.2	F = 0.24, ns
Pukeko	48	2.9 ± 6.0	40	3.9 ± 7.0	F = 0.54, ns
Duck	48	2.0 ± 4.7	40	0.65 ± 1.95	F = 2.2, ns
Paradise Duck	48	1.5 ± 2.38	40	2.1 ± 3.8	F = 0.72, ns

Table 6b: Abundance of birds in farmland in the non-treatment area in Period 1 and Period 2. The counts are of individuals seen on 8 sections of road, totaling 104 km, in the non-treatment area. The 8 sections of road were counted 7 times in Period 1 and 5 times in Period 2.

Species	N	Period 1	N	Period 2	F-test and significance
Magpie	56	5.3 ± 6.1	40	9.1 ± 8.3	F = 6.6, P < 0.00
Harrier	56	0.56 ± 1.07	40	1.1 ± 1.6	F= 3.83, P = 0.05
Turkey	56	1.2 ± 3.0	40	2.9 ± 5.4	F = 3.9, P < 0.05
Feral Goose	56	1.6 ± 7.0	40	4.7 ± 11.7	F = 2.57, ns
Pheasant	56	0.23 ± 0.60	40	0.15 ± 0.67	F = 1.05, ns
Californian Quail	56	0.84 ± 1.6	40	1.3 ± 3.2	F = 0.9, ns
Pukeko	56	0.16 ± 0.56	40	0.20 ± 7.0	F = 0.09, ns
Duck	56	1.4 ± 3.7	40	0.65 ± 1.95	F = 0.8, ns
Paradise duck	56	4.5 ± 13.7	40	4.8 ± 13.65	F = 0.1, ns

The road counts were of little use for assessing the abundance of top-predators because so few were encountered (Table 7a and 7b). Actual sightings of live animals were limited to one stoat and 6 cats. Ferrets and weasels were not recorded at all, either as live animals or as road kills. The counts were, however, more useful for indexing the abundance of rabbits and hares, neither of which varied significantly between counting areas, or between time periods.

Table 7a: Abundance of selected mammals in farmland in the footprint in Period 1 and Period 2. Conventions as for Table 6a.

Species	N	Period 1	N	Period 2	F-test and significance
Rabbit (seen)	48	1.4 ± 2.4	40	1.0 ± 1.7	F = 0.87, ns
Rabbit (killed)	48	0.25 ± 0.53	40	0.30 ± 0.6	F= 0.18, ns
Hares (seen)	48	0.60 ± 1.7	40	0.62 ± 1.14	F = 0.01, ns
Possum (killed)	48	0.20 ± 0.58	40	0.15 ± 0.42	F = 2.78, ns
Stoat (seen)	48	0.10 ± 0.37	40	0 ± 0	F = 0.8, ns
Cat (Seen)	48	0.10 ± 0.37	40	0 ± 0	F = 3.14, ns
Hedgehog (killed)	48	0.06 ± 0.24	40	0.10 ± 0.3	F = 0.41, ns

Table 7b: Abundance of selected mammals in farmland in the non-treatment area in Period 1 and Period 2. Conventions as for Table 6b.

Species	N	Period 1	N	Period 2	F-test and significance
Rabbit (seen)	56	1.6 ± 2.4	40	0.8 ± 1.0	F = 3.8, ns
Rabbit (killed)	56	0.26 ± 0.69	40	0.28 ± 0.51	F= 0.02, ns
Hares (seen)	56	0.21 ± 0.49	40	0.25 ± 0.55	F = 0.2, ns
Possum (killed)	56	0.20 ± 0.13	40	0.05 ± 0.22	F = 0.17, ns
Stoat (seen)	56	0 ± 0	40	0 ± 0	F = 0, ns
Cat (Seen)	56	0 ± 0	40	0.03 ± 0.16	F = 1.46, ns
Hedgehog (killed)	56	0.24 ± 0.54	40	0.18 ± 0.45	F = 0.39, ns

3) Power analyses and sample size

The results in Tables 2a & 2b provide a strong indication of the power of the existing sampling programme when analysed for effect size and significance. In Fig 1, the graph on the left plots differences between means that did not reach the 5% significance threshold, in relation to the size of the mean in the first count, (i.e. the number of individuals detected per 5-minutes in the first count) and the % change from the original mean in the subsequent count (for example between Period 1 and Period 2, or between two counting areas). The graph on the right shows the differences that did exceed the 5% significance threshold.

The two graphs between them show that the current sampling programme is generally achieving its design brief and detecting an absolute effect size of ≥ 20%. In other words, with current sample sizes, differences between means of ≥ 20% are generally significant while those of ≤ 20% are generally not. There are two exceptions: effect sizes of ≥ 20% are sometimes not significant in species which are recorded very rarely in counts, while effect sizes of ≤ 20% are sometimes significant in species which are recorded very frequently in counts. Amongst natives, kereru is an example of an infrequently encountered species that may or may not reach the 5% significance threshold with an effect size of ≥ 20%.

In power analyses (G* Power 3.1www.gpower.hhu.de/.../gpower/GPower31-BRM-Paper.pdf) effect size (d) is calculated as: (Mean 1- Mean 2)/standard deviation of the difference between means. Clearly this is not the same as the percentage difference between two means; and an effect size (d) of 0.20 is therefore not equivalent to a ± 20% difference between means. However, effect size (d) is correlated with the % difference between means, as shown in Fig. 2.

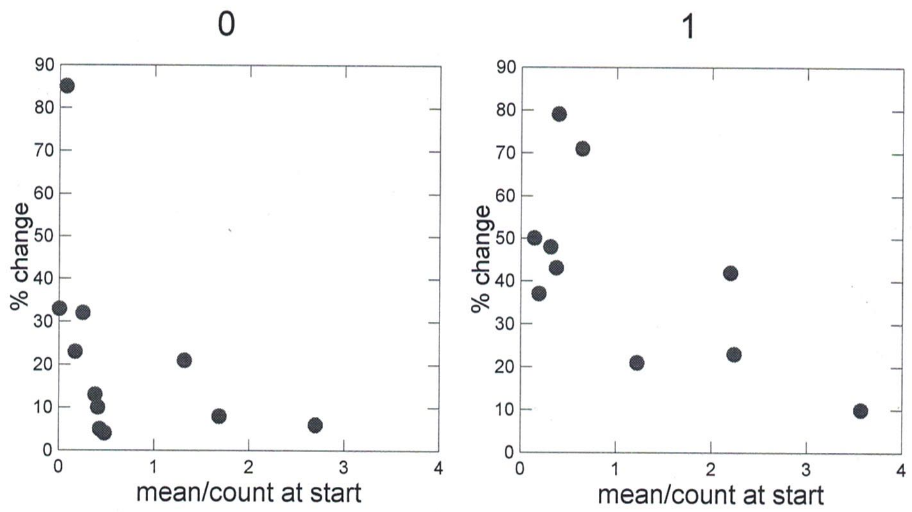

Fig. 1: The relationship between effect size and mean number of individuals per count, calculated from the data in Tables 2a and 2 b. Effect size is the % difference between the means in the first and second count. Mean per count at the start is the mean value for that species in the first set of counts. The left hand graph, marked 0, plots the values that were not significant at P < 0.05 or greater. The right hand graph, marked 1, plots the values that were significant.

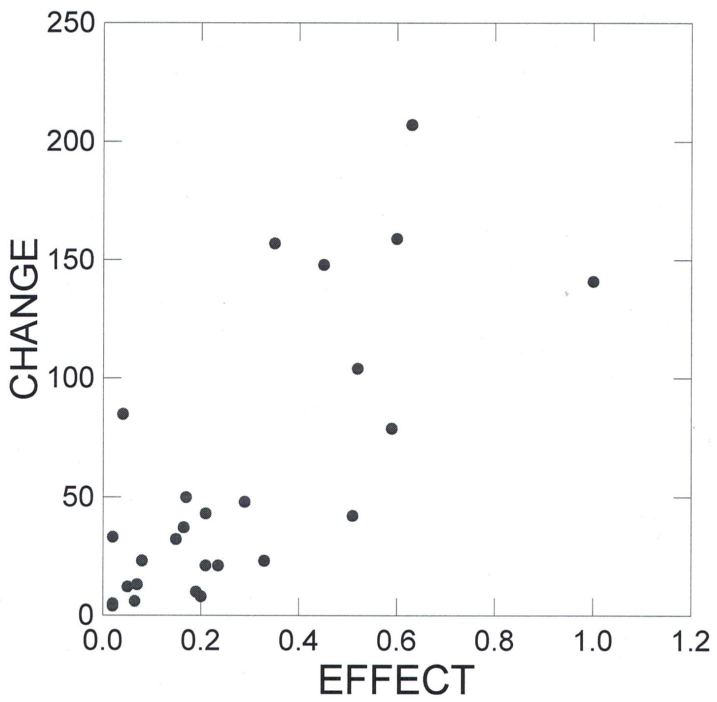

Fig. 2: The relationship between Effect size (d) and change (% difference between means) for the counts in Tables 2a and 2 b. Effect size (d) is the effect size calculated by the program G* Power.

In Tables 2a and 2b, effect sizes (d) of 0.20 or greater were generally significant (at P < .05). The smallest effect size (d) that was significant was 0.165, while the largest one that was not significant was 0.235. Fig. 2 shows that an absolute difference of 20% between counts (either up or down) corresponds to an effect size (d) within the range of 0.15 - 0.35. The sample sizes required to detect significant differences for effect sizes (d) within this range, with a power of 90%, are shown in Table 8.

Table 8: Number of 5 minute counts required to detect a significant difference (at 0.05 level) between two independent samples, with Power = 0.90, and effect sizes (d) ranging from 0.15 - 0.35.

Effect size (d)	Sample size (Number of 5 minute counts)		
	Sample 1	Sample 2	Total
0.15	935	935	1870
0.20	527	527	1054
0.25	338	338	676
0.30	235	235	470
0.35	173	173	346

A comparison of sample sizes in Table 2 (a,b,c) and Table 8 shows that the current sampling programme should generally detect effect sizes (d) in the range of 0.20 to 0.30 on 90% of occasions, exactly in line with expectations. In other words, the formal Power analyses confirm the general pattern evident in Fig 1.

Similar analyses for the road counts (Tables 7a and 7b) show that they are currently capable of detecting effect sizes (d) of ≥ 0.60, corresponding to differences between means ≥ 100%. If required, their power could be increased at any time in the future, by doing more of them.

4) Loss of counting sites and maintenance of sample size

The sites at which birds were counted are described in Table 2 of McLennan (2017). In 2017, Transect 5 (Julian Gully) was lost to harvesting., taking with it 10 count stations in pine forest in the footprint. In 2018, harvesting began in other pine forests in the footprint and non-treatment area, resulting in the complete or partial loss of Transect 7 (Winirana Forest East 1); Transect 8 (Winiarana Forest East 2); Transect 9 (Winirana East 3); Transect 10 (Winirana West); Transects 15 and 16 (Hapua Forest) and Transect 17 (Arborfield Forest). Between them, these transects accounted for 50% of all counting sites, and for 75% of the counting sites in pine forests. There are now no counting sites in pine forests in the non-treatment area, and just 10 surviving counting sites in pine forests in the footprint. Clearly, all of these counting sites will need to be replaced, if the sampling programme is to retain its current power.

Discussion

Variation in bird abundance in the counting areas

The additional results from the 2017 and 2018 monitoring programme show that bird abundance within the three counting areas is highly variable, in part because of natural changes of unknown cause, and in part because of the species management programmes in both *Cape Sanctuary* and the Cape to City footprint. The response of some native species to predator control was expected, given that they have a history of doing it elsewhere; but the abundance changes resulting from natural causes were surprising, both in their magnitude, and in the range of species affected.

Increasingly, birds are being monitored as environmental indicators (Mekonen, 2017) mainly because they are widespread, highly visible and generally easy to count. Numerous examples now exist of birds signaling a change in an environmental parameter that might otherwise have passed unnoticed. However, in this study, the large generic changes in abundance noted for some species appear to have no common cause or clear signal. For example, the decline of shinning cuckoo appears to be completely unrelated to the increase in magpie abundance; and the pronounced decline of greenfinches is hard to interpret when other finches (goldfinch and chaffinch) maintained their numbers.

The signals (if any) become even harder to interpret when the results of this study are compared with those of the NZ wide garden bird survey, over the period 2007-2017 (Table 9). The comparative results for greenfinch are diametrically opposed, as are the results for starling and silvereye. This may simply be a consequence of the different time periods in the comparison: the results of the garden bird survey are presented as a longterm average, rather than year by year, so it is not possible to tell whether the more recent counts align or depart from the longterm trends.

For now, the cause of the natural variation in the bird counts in the three counting areas in the Cape to City study remains unknown. The results do, however, highlight the value of the non-treatment area, and its role in distinguishing natural abundance changes from management-induced ones within the footprint itself.

Responses of birds to management in the footprint

McLennan (2017) noted that *"a successful C2C programme would produce the following outcomes for native birds in the footprint: a marked increase in the abundance and distribution of pateke and kakariki; viable populations of robins, tomtits and whiteheads in suitable habitats; an overall increase in the abundance of kereru, tui and bellbirds; and increased breeding success of various species (rifleman included) already resident in old growth forests on the Maraetotara Plateau. These outcomes would profoundly change the avian community in the footprint, by increasing both native species dominance and levels of endemism."*

Table 9: Comparative results of this study and the NZ Garden bird Survey ((MacLeod et.al., 2018). It is important to note that the time periods of the two studies differ, so the comparisons are not strictly valid. The results shown for the garden bird study are those that were collected from the Hawkes Bay region.

Species	This study (2015-2018)	NZ garden bird survey 2007-2017
Chaffinch	No change	Shallow increase
Greenfinch	Steep decline	Rapid Increase
Goldfinch	No change	No change
House sparrow	Shallow decline	Shallow decline
Blackbird	Shallow decline	No change
Thrush	Shallow decline	Shallow decline
Magpie	Rapid increase	Not measured
Starling	Shallow increase	Rapid decline
Myna	No change, but absent in counting areas	Shallow increase
Tui	Shallow increase	Shallow increase
Bellbird	Shallow increase	Shallow increase
Kereru	No change	Moderate Increase
Silvereye	Rapid increase	Shallow decline
Fantail	Shallow increase	Shallow increase

The monitoring results from 2017and 2018 (Table 3) indicate that some of these measures of success are beginning to materialize. Robin, tui, bellbird and rifleman are now more abundant in the footprint than they were in 2015/16. So too are silvereye, grey warbler and fantail, in part because of the rat and top-predator control programme at the northern end of the footprint. These results are encouraging, and hint of other changes that are yet to come. The individual results for robin and rifleman are outstanding, the former because of their rapid increase and expansion in the footprint, and the latter because of the growth of their localised and isolated population on the Maraetotara Plateau, an outcome that runs counter to the trend exhibited by the species nationwide (Robertson et. al, 2012).

Whitehead and tomtit have not managed to establish viable populations in the footprint, even though the first founders (presumably of *Cape Sanctuary* origin) were recorded in the northern end in 2016. The whiteheads were seen in a pine forest immediately alongside *Cape Sanctuary* that has since been logged. The tomtit (a single male) was seen in a different pine forest that has now also been logged. Another tomtit, seen on Te Mata Peak near Havelock North, has also disappeared, even though the habitat it occupied remains intact. The tomtit translocation programme to forests on the Mareatotara Plateau, undertaken as part of the Cape to City programme in 2016 (Nakagawa and McLennan 2018) failed to result in successful population establishment, a common outcome for what is now recognised as a 'hard to translocate' species.

It is now doubtful that whiteheads and tomtits will ever move naturally from *Cape Sanctuary* to the footprint even though *Cape Sanctuary* continues to support sizeable 'source' populations of both species. All mature pine forests in the northern end of the footprint have been (or are currently being) milled, removing the valuable stepping stones that formerly linked the sanctuary to the central and southern parts of the footprint. The harvesting of these stepping stones has also removed valuable habitat for small insectivores, exacerbating a shortage in a landscape that already had little of it. Despite the inherent difficulties, tomtit and whitehead probably now need to be physically transported to the southern end of the footprint if they are to take advantage of the forests there.

The movement of kakariki from the sanctuary to the footprint has also been infrequent and slow. No kakariki were recorded in counts in the footprint but they are seen there from time to time by resident landowners. A pair attempted to nest in a hole in a willow on the banks of the Maraetotara River in 2017, but failed, apparently because of stoat predation (John Winters, pers. comm.). Kakariki are capable of long distance flights over farmland, so may eventually colonise the native forests at the southern end of the footprint in time. The counts show the source population of kakariki in *Cape Sanctuary* is continuing to grow, potentially increasing the supply of dispersers.

McLennan (2017) noted *"the degree to which threatened native birds of Cape Sanctuary origin colonise the C2C footprint following the onset of top-predator control will ultimately be determined by four factors: 1) the success of the predator control programme; 2) the quantity and quality of habitats available for occupation within the footprint itself, 3) the ability and propensity of individual species to disperse over open farmland from Cape Sanctuary to isolated patches of forest within the C2C footprint, and 4) the extent to which the sanctuary generates a supply of potential colonists for the C2C footprint."*

The counts in 2017 and 2018 indicate that Factor 2 will ultimately determine the overall success of the Cape to City programme, as indicated by the response of native birds. There are currently few places in the footprint where native birds can live, a limitation that will take decades to remedy, regardless of whether the recently milled pine forests are re-planted, or whether the pace of native plantings accelerates as more emphasis is put on global warming and erosion control. The living places that do exist will soon be fully occupied, especially if (as already mentioned) translocations of poor dispersers are undertaken to accelerate rates of colonisation.

It is therefore important to acknowledge that native birds may be a relatively poor indicator of the overall success of the Cape to City programme. The programme itself may well achieve its ambitious technical target - effective low-cost large predator control over 26,000 ha - without generating a commensurate response from rare and endangered native birds. This also means the intent to make the bird communities of *Cape Sanctuary* and the footprint 'one and the same' is unlikely to be realised. It might have been if the same experiment had been run in a heavily wooded landscape, similar to, for example, those in northern Taranaki.

The next set of counts, in 3-5 years time, will show exactly just how large the response of birds in the footprint will eventually be. It will be interesting to see what unfolds.

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