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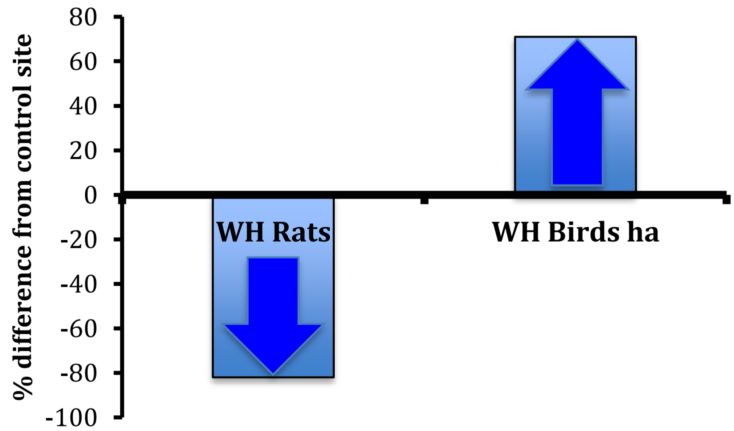
WINDY HILL ROSALIE BAY CATCHMENT TRUST

BIRD COUNTS DECEMBER 2017 and ANALYSIS of A DECADE OF DATA (2008 to 2017).

REPORT JO 14. MARCH 2018.

Biodiversity and Pest species changes in Windy Hill Sanctuary relative to the Control site. Averaged over 10 years.



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BIRD COUNTS: DECEMBER 2017

EXECUTIVE SUMMARY

Since 2000 the Windy Hill Rosalie Bay Catchment Trust has undertaken a programme of pest management, aimed at reducing rats to low numbers in 'The Sanctuary'. The managed area has increased through time and various (unmanaged) controls have been designated.

Three-minute bird counts have been made in December, at the same points and mostly by the same observers at Windy Hill every year since 2000. The results have been reported annually, and the field and analysis methods described previously.

In 2017, three former control sites became managed as part of the Taumata block. Consequently 276 counts were made in eight separate locations within the Sanctuary area, and only 72 in three locations designated controls.

The inverse relationship between rat abundance (as indicated by tracking tunnel %s) and bird abundance has been clearly demonstrated over a 10-year period.

Rat abundance has declined in both managed and unmanaged areas since 2008, although it remains high in the latter, inhibiting bird increase.

There is evidence of a 'spill over' effect; increased bird productivity in the managed area boosting numbers in adjacent areas such as the controls, and the Taumata block.

There was a significant increase in 'total bird density' and the density of both tui and grey warbler after one year of management in the Taumata block.

The difference between managed and unmanaged areas, clear in all previous reports, remains so and is verified statistically in this report. Bird density in the managed area is about double that in the unmanaged controls. The persistent, statistically significant, differences in bird density between managed and unmanaged areas at Windy Hill may be some of the best data available illustrating the benefits of intensive pest reduction without total eradication.

The overall long-term trend of increasing numbers for most species in the Sanctuary continued. Tui and grey warbler show statistically significant increasing trends.

Kereru are more abundant in managed compared to unmanaged areas; the upwards trend in the Sanctuary continued in 2017, but is not yet statistically significant.

Silvereye continued their downward trend in the Sanctuary in 2017, but there was no evidence that this could be associated with pecking at toxic baits.

It is estimated that rat management is saving c 3500 birds annually in the 770 ha. Sanctuary.

INTRODUCTION

This report: This report is one of an annual series and is presented in the format used in the previous Reports. It covers the analysis of 3-minute bird count data sets from Windy Hill Rosalie Bay Catchment Trust Management Area in December 2017. Comparison is made between managed areas (in which rat numbers are kept low by the use of traps and bait stations) and unmanaged control areas. A new managed area, Taumata, was included with two new transects in 2017. (The 2016 Taumata control became a managed area). The 2016 data are compared with similar data collected each year since 2008 and trends are plotted.

Previous reports etc.: The bird monitoring project has been outlined in previous reports and papers. Reports before 2008 were by ECoRAP (Dr S. Ferreira and Anne-Marie Smit) and cover the period from the commencement of monitoring in 2000 to June 2008. The overall conclusions to be drawn from these earlier reports are summarised in Ogden, J. 2009. *WHRBCT Bird Counts December 2008*, and EcoRAP report: EC0006/12-8. *Bird Counts June 2008.* September 2008; all indicate general ecosystem improvement since restoration began in 2000[1].

Pest management within the Windy Hill Rosalie Bay Catchment Trust Sanctuary (WHRBCT): The WHRBCT is a community conservation group focussed on pest control and ecosystem restoration on fifteen mainly private properties in south-east Great Barrier Island. The managed area now covers c. 770ha, and the trust employs up to six field staff and volunteers, mainly engaged in pest management, but also monitoring birds, reptiles, invertebrates, stream fauna and forest tree seedling populations as well as project administration. One of the main strengths of the Trust has been in testing methodology (e.g. different rodent control and monitoring methods), reporting negative results, and providing transparency on the costs and benefits of its operations.

Vegetation at Windy Hill: As described in earlier Reports, the forest cover of the area forms a continuum from manuka dominance on ridges, through kanuka, to progressively richer and taller forest, especially in the valleys. The composition and structure of the kanuka dominated forest types – which cover most of the landscape - is changing as succession towards more mature canopies continues. This quite rapid change in forest structure and condition has been described[2] and should be kept in mind when assessing changing bird abundances.

Bird monitoring: Bird monitoring has played an important part in evaluating the management actions of the Windy Hill Rosalie Bay Catchment Trust since 2000. Monitoring

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[1] Ogden, J. & Gilbert, J. 2005. *Rodent trapping results from Windy Hill and Benthorn farm, Great Barrier Island: 1999-2004*. Ogden, J. & Gilbert, J. 2009. *Prospects for the eradication of rats from a large inhabited island: community based ecosystem studies on Great Barrier Island, New Zealand*. Biological Invasions: 11: 1705-1717. Ogden, J. 2009. Windy Hill Rosalie Bay Catchment Trust. *Bird Counts December 2008*, Report JO1. February 2009. Ogden, J. 2011. Windy Hill Rosalie Bay Catchment Trust. *Trends in Bird Abundance 2000 – 2011*. Report JO5. July 2011. Ogden, J. 2011. Windy Hill Rosalie Bay Catchment Trust. *Bird Counts December 2010,* Report JO4. February 2011.

[2] Perry, G.L.W., Ogden, J., Enright, N. J. & Davy, L.V. 2010. Vegetation patterns and trajectories in disturbed landscapes, Great Barrier Island, Northern New Zealand. *New Zealand Journal of Ecology* 34(3): 311-323.

has been carried out over some of the same transects over this whole period, and new areas have been added. The necessity to compare different areas and vegetation types, and to replicate bird counts both spatially within a locality (e.g. ridge or valley) and at different seasons, was recognised, making this one of the longest and most comprehensive bird monitoring studies on private land in New Zealand. However, as the seasonal changes in species abundance/conspicuousness were predictable and similar each year, and were not the prime focus of the work, they were discontinued. Since 2009 formal bird monitoring has been restricted to one week during December with a view to recording only data essential to assessing the long-term effects of predator management and reducing costs.

METHODS

Data collection

Three-minute bird counts were made at 46 point-stations on transect lines in eight locations within the managed area ("The Sanctuary") and at 12 point-stations in three unmanaged locations outside it ("The Controls"). These areas are named (or given abbreviations) in Table 1. The Sanctuary or managed area refers to the c. 770 ha area in which rat trapping and bait stations are employed; rodent monitoring tunnels are also employed in both managed and unmanaged areas. Note that in 2017 three locations (Taumata Bush, Taumata Rosalie Bay Road, and Little Goat Road) which were unmanaged controls in 2016 became 'managed'.

All points were counted on six occasions, over a period of seven days, giving a total of 348 3-minute observations The counting transects are each 150m in length, with count points marked by a stake at each end. Intermediate 50m points were *not* counted, but casual bird observations were noted. There were six observers, over the period 1st to 7th December. Most locations were sampled by two observers, but on any one day the controls were mostly counted by single individuals (Table 1). A preliminary analysis suggested that this did not result in any bias.

The survey technique was as follows:

- At each station, birds were counted for 3 minutes.
- Individuals heard and/or seen were counted, with care taken to ensure that each individual was recorded once only.
- For each bird recorded, the distance from the station to the bird was estimated in 5m classes as follows: 0 -5m, >5-10m, >10-15m, >15-20m, >20-25m.

Since 2009 recorders have noted 'additional' birds calling > 25m from the point or between points in the margins of the data sheet. This was done to make the counts more comparable with those carried out between 2006 – 2008 by the Great Barrier Island Charitable Trust[3].

[3] Great Barrier Island Charitable Trust. Biodiversity Advice Fund AV 207; Final Report.

Disregarding the 'additional' birds, and bearing in mind the difficulty of visually or audibly assessing station-bird distances in forest, each station surveys an area of approximately 25m radius (1963.5m^2).

Table 1. Sample sizes, dates and observers for the December 3-minute counts, 2017[4]

Location	Points	Total counts (Points x 6 reps)	Start date	End date	Observers (1)
Ridges (R1 - R6)	12	72	1-Dec	5-Dec	R, A, K, D.
Valleys (V1 - V6)	12	72	1-Dec	5-Dec	R, A, K, D.
Benthorn	4	24	6-Dec	7-Dec	R. K.
Robin area	4	24	1-Dec	7-Dec	A, K.
Rosalie Bay & Big Windy	4	24	1-Dec	6-Dec	K, H
Taumata (Ros Bay Rd)	4	24	1-Dec	6-Dec	H, A.
Taumata (Bush)	4	24	1-Dec	6-Dec	H, A.
Little Goat (former control)	2	12	1-Dec	5-Dec	H, A
ALL SANCTUARY	**46**	**276**	**1-Dec**	**7-Dec**	**5 observers**
Old control	4	24	4-Dec	6-Dec	R, K.
Waterfall Bay control	4	24	4-Dec	4-Dec	Dv, H.
Rosalie Bay rd. control	4	24	1-Dec	6-Dec	H, K.
ALL CONTROLS	**12**	**72**	**1-Dec**	**6-Dec**	**5 observers**
TOTALS	***58***	***348***	***1-Dec***	***7-Dec***	***6 observers***

(1) Observers: H, Henry Cookson; R, Rachel Wakefield; Dv, Dave Harland. D. Dean Medland, A, Abby Naismith. K, Kevin Parsons.

In 2017 three quarters of counts (276) were made in eight separate locations within the managed area, and the remainder in three unmanaged control locations.

Data analysis

Analysis methodology has been given in more detail in previous reports. It is important to recognize that bird *conspicuousness* varies with species, vegetation type, season, time of day, weather conditions etc. Consequently 3-minute bird counts are difficult to interpret: they will not usually reflect the *actual number* of birds present. Consequently it is important to replicate counts and to be cautious in interpretation.

The 3-minute counts were usually carried out from c. 9.0AM to midday, but some repeats were in afternoons, until c. 3.0 PM. All stations were replicated six times, but the interval between replications varied from hours to days. Spreading the work between observers over a

[4] [WH 2017 anal 2016 data: Tabs 1, 2, 3 2016 .xlsx]

week has the advantage of 'averaging out' differences due to weather and possible differences in observer ability. The total survey sample comprises 348 three-minute counts, representing over 17 hours of observations, but considerably more travel time (estimated c. 200 person-hours).

Two ways of summarizing the 3-minute data are presented:

1) *Count frequency:* frequency for a species based on the number of times a species was recorded as present at a site, divided by the total number of site-counts (eg, if a bird was seen or heard on 25 occasions at the 72 station counts on Windy Hill ridges, it would have a frequency (on WH ridges) of 25/72 = 35%)
2) *Density(estimated number per hectare)*: based on the sum of the numbers counted at points at any one time (rather than simply 'present'). Counts per station are converted into per ha values by multiplying by 5.09296. The multiplier is 1/0.19635, i.e. the number of point centred sample areas of 25m radius in a hectare. Note that the separate distance categories recorded in the raw data have *not* been used to make more precise estimates of density.

   An important reason for adopting this simplified approach to data analysis and presentation is that there are serious doubts as to how reliable 3-minute count data are for estimating 'true' density (numbers per ha.). This is because what is really being measured is the 'conspicuousness' of the different species.

   The standard deviation (S) of the density estimates for each species have been converted into 95% Confidence Limits (95%CL = S/(sq. root N) * 1.96).

The first measure (count frequency) cannot exceed 1.0 (100%) for any species. When based on a large sample size (as here) the percentage value relates directly to the *probability* of recording the species at a site. Frequency is an easy measure to compare between sites and times, and is robust even when fieldwork is carried out by different observers.

Density is intended to be an absolute (nos./ha) figure rather than simply a relative value or probability. However, it is also influenced by differences in conspicuousness and, when most data sets contain many zero entries, is likely to have a wide variance. Density is estimated for each species in each location by: (1) assuming that the number counted for a species at a station in the field data represent the number of individuals < 25m from the station, and (2) converting the number of birds in the circle represented by 25m radius to a hectare sample by multiplying by 5.0929. This method takes no account of the detailed 'distance' measures (other than 'within 25m') and may underestimate small inconspicuous birds. It gives equal weight to a sighting or hearing at 5m as to one at 25m. However, more 'refined' analyses employing distance probability functions produced unrealistic estimates, especially for flocking species, which violate a fundamental assumption of the model[5]. As demonstrated in an earlier Report[6], frequency and density are strongly correlated statistically, so the former reflects the latter. This of course is to be expected – the more numerous a species is, the higher the probability that it will be recorded at any location.

Statistical methods

The 95% Confidence limits (95% CL) used in the figures in earlier reports and in Figs 6 and 7 here, are a measure of the variability of the average estimate in the repeated counts[7]. Where confidence limits overlap extensively between compared averages, we can conclude that there is no statistically significant difference between them. A more formal *t- test* almost invariably supports this interpretation, but is a more sensitive test, especially where data points can logically be paired, as, for example, when comparing the same species across the same sites in two different years.

T-tests. Where 95% CLs *do not* overlap it is likely that there is a real difference. This conclusion is usually supported by *t-test* results giving low *p* (probability) and is particularly likely for situations where the lack of overlap is clear and repeated over several years (e.g. between WH Ridges and Control in 5 out of 7 years). T-tests measure the probability that two means (derived from two sets of data) are likely to be different, or alternatively just different estimates of the overall mean of both data sets. Statistical probability is the probability of the observed statistic value being due to chance alone – thus $p< 0.05$ means that there is less than 5% probability that the value (*t*, or *r*) is due to chance sampling, or conversely that there is a 95% chance that it represents a real 'significant' difference. Different levels of probability are usually represented by asterisks as follows: p<.05 *; <.01 **: <.001 ***. The more stars, the more 'significant' the result.

The wide variability in the Windy Hill bird count results implies that selected pair-wise t-tests taken from such a large body of data must be treated cautiously; using a probability value of < 0.05 (5%), five out of every 100 such tests could be incorrectly regarded as 'significant'. Consequently low levels of significance ($p < 0.10$ (*) or $p < 0.05$ *, should be regarded skeptically unless supported by other results. (*Analysis of Variance* ANOVA might be considered preferable for multivariate data sets such as bird species densities at various sites over 10 years but has not been used here due to lack of an appropriate statistical computer package available to the author).

The Correlation Coefficient is a robust statistic for comparing two data sets that can be paired, such as bird density in sequential years, or species A with species B over a series of years. *Spearman's Rank Correlation Coefficient* compares ranks; for example, from commonest bird to rarest in two sites or time periods. Both correlation coefficients range

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[5] The model assumes 'uniform distribution' of the items being sampled with respect to the sample transects (or points). Cassey, P. & McArdle, B. H. 1999. An assessment of distance sampling techniques for estimating animal abundance. *Environmetrics* 10: 261-278. See also: Cassey, P. 1999. Estimating animal abundance by distance sapling techniques. *Conservation Advisory Science Notes.* No. 237. Dept. of Conservation, Wellington. A key text is: Buckland, S. T. et al. 1993. *Distance Sampling. Estimating Abundance of Biological Populations.* Chapman and Hall. London, UK.

[6] Windy Hill Rosalie Bay Catchment Trust. Bird Counts. December 2012, Fig. 9. (Report JO 7. March 2013.)

[7] 95% CL =(standard deviation/squareroot n)*1.96, expressed as ± the mean value

from +1 (when the variable values or rankings exactly agree) to -1 (when the compared data sets are exactly opposite).

RESULTS

Overall bird frequency trends 2008 – 2017

Frequency measures the % likelihood of seeing or hearing a bird within 25 m, in a 3-minute period. Table 2 demonstrates that birds (all species combined) are generally about 9% more frequent in the managed than in the unmanaged areas. Although variable from year to year, this difference appears to have been declining. In 2017 the difference between managed and unmanaged areas may have further declined, possibly reflecting an approaching plateau in bird frequency in the managed area (frequency cannot exceed 100%). Individual species frequency data for 2017 are summarised in Table 3, with tui emphasised. The data illustrate the variability of the frequency measure from year to year, but also demonstrate the increase in tui frequency, especially in the controls.

Table 2. Total bird frequencies (all species) in the managed and unmanaged (control) areas at Windy Hill over ten years. The % difference row is the relative increase of the managed over the unmanaged area[8].

Transect	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Avg.
Ridges	72	80	77	82	87	85	78	83	89	92	82.5
Valleys	73	73	78	82	87	83	86	92	85	90	82.9
Benthorn	88	81	77	73	85	85	91	87	100	83	85.0
Robin	60	69	77	81	90	83	79	92	92	71	79.4
Rosalie/BW						96	83	92	83	83	87.4
Taumata RB										79	79.0
Taumata Bush										75	75.0
Little Goat Mangd										92	92.0
Old Control	58	29	50	71	83	75	71	50	71	79	63.7
Waterfall Bay con.				56		50	67	50	83	75	63.5
Ros. Bay control								79	58	75	70.7
Taumata RB									96		96.0
Little Goat control								83	83		83.0
Avg managed	73.3	75.8	77.3	79.5	87.3	86.4	83.4	89.2	89.8	83.1	82.9
Avg unmanaged	58.0	29.0	50.0	63.5	83.0	62.5	69.0	65.5	78.2	76.3	75.4
Difference (%)	20.8	61.7	35.3	20.1	4.9	27.7	17.3	26.6	12.9	8.2	9.1

[8] Tables 2 and 3 see: [WH 2017 2018] Tabs 1,2,3 2017 data.xlsx.

The overall frequency data are also shown in Fig 1, which illustrates the trend of increasing bird frequency in both managed and unmanaged areas. While the overall rate of increase in the unmanaged areas (lower dotted line in Fig 1) is steeper, there is much more variability than in the managed area. Both trends are statistically significant. (Correlation Coefficient, r (managed = 0..65; P>.0.05. unmanaged = 0.68; P>0.05). The more consistent trend in the managed area is closer to the maximum possible frequency (100%) than the unmanaged. The decline in overall bird frequency in 2017 can likely be attributed to the addition of new areas managed for only one year.

Table 3. Frequencies by species in managed (Sanctuary) and unmanaged control areas in 2017 compared to two previous years.

Species	All Sanctuary			All Controls		
	2015	2016	2017	2015	2016	2017
Kaka	25.5	22.2	15.7	11.9	14.2	13.1
Silvereye	14.3	28.1	12.9	8.3	20.0	10.1
Tui	39.3	43.9	48.6	9.5	11.7	28.1
S. cuckoo	4.6	1.9	1.4	0.0	0.0	1.1
Grey warbler	32.9	28.1	29.2	34.5	16.7	35.0
Fantail	17.1	20.6	17.7	11.9	23.3	14.4
Kingfisher	11.6	17.5	8.1	3.6	14.2	9.1
Kereru	18.5	21.9	17.3	3.6	10.8	7.6
Robin	0.0	0.0	0.0	0.0	0.0	0.0
Other	5.5	7.5	9.9	3.6	3.3	4.5
All bird species	88.4	80.0	81.9	63.1	78.3	80.6

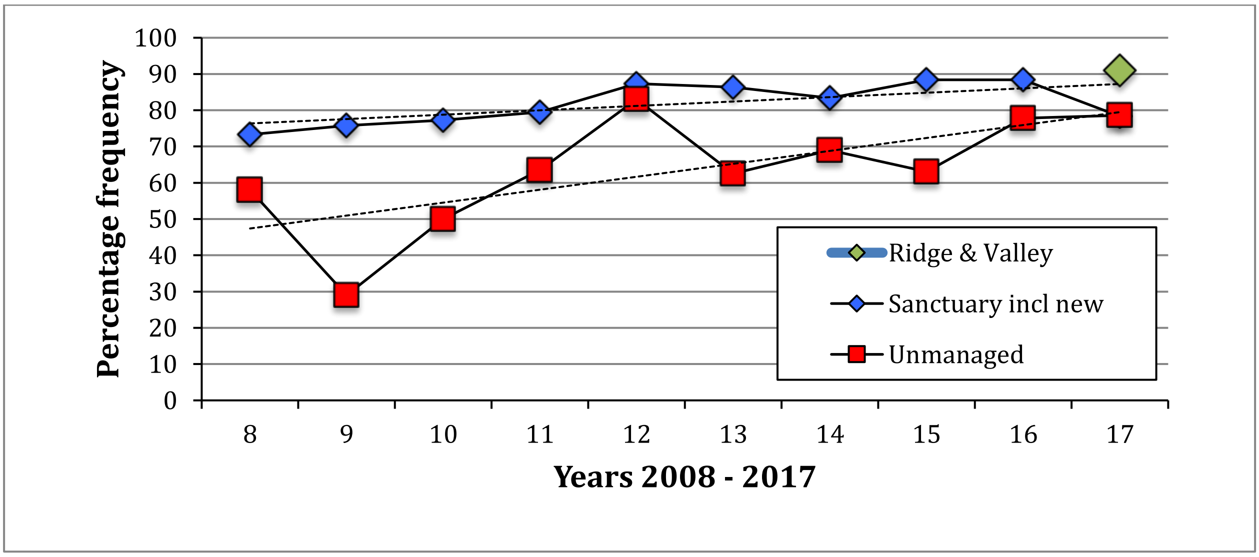


Fig 1. Frequency trends for all species over 10 years in Managed areas (Sanctuary including

new transects), and unmanaged control areas. Dashed lines are overall linear trends. Ridge and Valley (sanctuary) data also added separately for 2017 only[9].

Species density trends 2008 – 2017.

The total (all species) bird count density results for each area in each year are included in the Appendix.

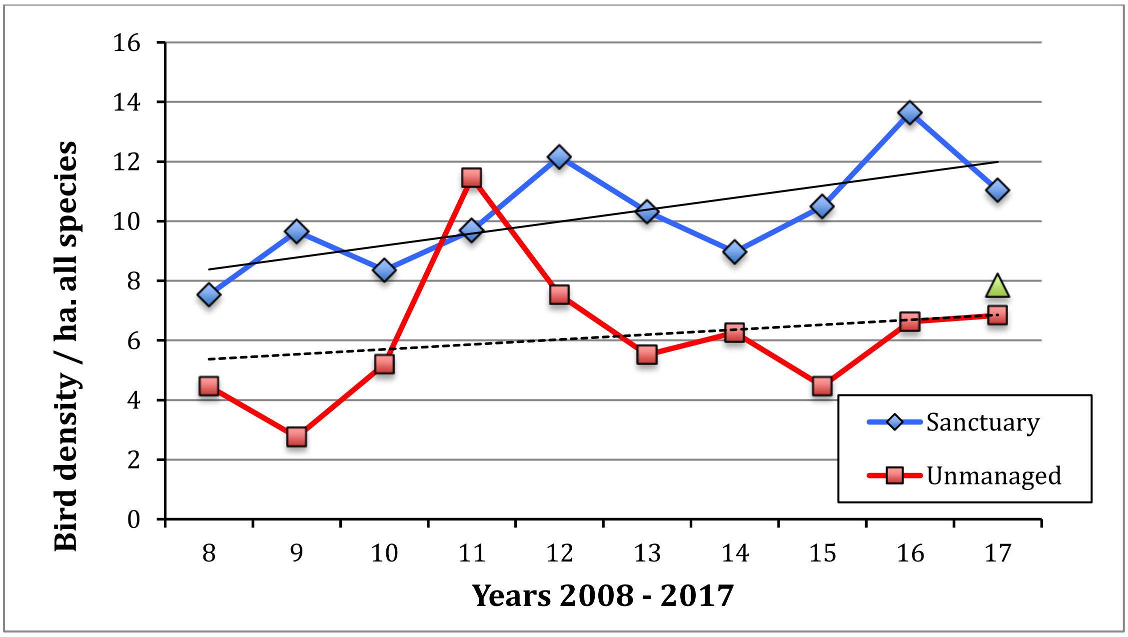


Fig 2. Average density (all bird species) per ha. in managed (Sanctuary)(upper blue line) and unmanaged areas (lower red line) over ten years[10]*. The green triangle is the average for two areas monitored in Taumata. The solid trend line is statistically significant.*

The density data (Fig 2), as expected, illustrate the same trends as the frequency data, but the difference between managed (sanctuary) areas and the unmanaged controls is clearer (Correlation coefficient $r = 0.6759$, $P < .05$ for Sanctuary, not significant for unmanaged area). Taken with the frequency data, the bird abundance trend is clearly upwards. In 2017 the Sanctuary recorded 11 birds/ha compared to c. 7 in the controls.

For individual species, density and frequency trends are similar, so only the former are given. Three general trends are presented (Table 4). First there are the trends over time (2008 – 2017) assessed using a correlation coefficient; this is presented only for the managed areas because trends were mainly much flatter for the controls. Second are the correlations between annual *fluctuations* in managed and unmanaged areas, and third, the overall difference in average density between managed and unmanaged areas.

[9] WH 2017 FIG 1. Frequency. Sanctuary v. Control. xlsx.
[10] Figs 2 and 3 in: [WH 2017 2018] WH 2017 FIG 2 FIG 4 DENS comparisons.xlsx]

Table 4 shows significant time-trends (increases) for tui and grey warbler. Although trends for other species except silvereye are all positive they do not individually reach statistical significance based on these averages. However, when all species are lumped, an overall increase in abundance in the managed area *is* statistically significant. Fluctuations in number from year to year show no clear pattern except for kaka, which apparently fluctuates in synchrony between managed and unmanaged areas.

Table 4. Statistical trends and comparisons for the main species and overall. The figures in Columns 2 and 3 are correlation coefficients (with significance levels); the figures in the last column are probabilities. The more stars the more significant the difference between managed and control areas.
** Significant (P< 0 .05); ** Very significant (P < 0.01); *** Very highly significant (P < 0.001).). NS, not significant (> 0.01) : (*) marginal significance p < 0.10).* [11]

Species	Time-trend correlation (r) in managed Sanctuary over 10 years	Coincidence of annual fluctuations between managed and control based on correlation coefficient.(r)	Difference in desity between managed and control based on paired t-test. P value.
Tui	0.9093***	0.4944 NS	.0005***
Kaka	0.4088 NS	0.7179*	.0009***
Kereru	0.3861 NS	-0.0043 NS	.0000***
Silvereye	-0.2676NS	0.4796 NS	0.0008***
Grey Warbler	0.6717 *	0.3921 NS	0.1951 NS
Fantail	0.0993 NS	0.4945 NS	0.0045**
All spp.	0.6759 *	0.2543 NS	0.0007***

Table 5. Significant differences between species densities on Ridges and Valleys, and comparisons of managed areas with the (Old) Control site, based on 10 years of data (2008-17). For significance levels of asterisks see Table 4.

Comparisons	Ridges v. Valleys	Comparisons with Control Site			
Location Species		Ridges	Valleys	Benthorn Farm	Robin Area
Kaka		*	**	**	
Silvereye	*	*		*	
Tui	**	**	*	*	
Shining Cuckoo	*			*	
Grey Warbler					
Fantail	***		**		*
Kingfisher		*	***	*	***
Kereru		**	**	**	**
Robin					*
Others				(*)	(*)

[11] WH 2016 Fig 4.xlsx (WH 2017 Fig 4; 2017 plus Tau); WH 2017 data anal trends.xlsx

The long-term trends for tui are clearly positive and also differ between the managed and control areas. All species except grey warbler show highly significantly higher densities in the managed areas compared to the unmanaged controls (last column in Table 4).

Taken over the 10 years, there are interesting differences between the ridge and valley transects (Table 5). While tui, silvereye and probably shining cuckoo are more abundant on the ridges, fantail is clearly more abundant in the damper gullies. Excepting the rare robin, and the ubiquitous grey warbler, all bird species show significantly greater abundance in at least two managed areas compared to the old control site (the only control site available for comparison over the whole ten-year period). Kereru and kingfisher are particularly clear in this respect.

Table 6 demonstrates that the main managed areas (Ridges, Valleys, Benthorn Farm and Big Windy-Rosalie Bay) are very similar in terms of species composition and density (mostly NS differences), but all differ very significantly from the controls. The Robin Area stands out as different to the other managed sites – but the presence of robins only in the Robin Area in years 2008 to 2013 probably accounts for most of this difference.

Table 6. Matrix of comparisons between sites; significant differences in species composition between sites – all species combined over 10 years. (Significance levels as in Table 4)

	Valleys	Benthorn Farm	Robin Area	Big Windy, Rosalie Bay	Old Control	Waterfall Bay Control
Ridges	NS	NS	***	NS	***	***
Valleys		NS	**	(*)	**	***
Bent. Fm.			***	**	***	***
Robin				NS	(*)	***
Big W, R.B.					*	***
Old Con.						**

Fig 3 shows the difference between the ridge and valley transects and the old control area for tui. Tui numbers have clearly increased more within the Sanctuary (Ridge & Valley transects) than in the Old Control. In the Sanctuary, an upwards trend from 2008 to 2012 was reversed in the next two years, when tui density apparently declined. Since then it has increased again. The trends in the ridges and valleys are highly correlated, but do not correlate with numerical trends in Benthorn, or with the controls.

Overall trends for the larger frugivores are given in Fig 4, and for the smaller insectivorous or omnivorous species in Fig 5. The figures clearly indicate the generally larger numbers of all species in the managed areas compared to the unmanaged controls, and also indicate the generally increasing trends over the last ten years.

Despite annual fluctuations, kaka appear to be trending upwards, and are generally commoner in the managed area than the unmanaged. Like Kereru, but for different reasons, *actual kaka numbers* are hard to estimate. The conspicuousness of the birds, and their loud calls, tend to cause over-estimation. This observation does not negate the difference between managed and unmanaged areas, or the time trends. Kereru may be slowly increasing in the managed areas, but numbers remain flat in the controls.

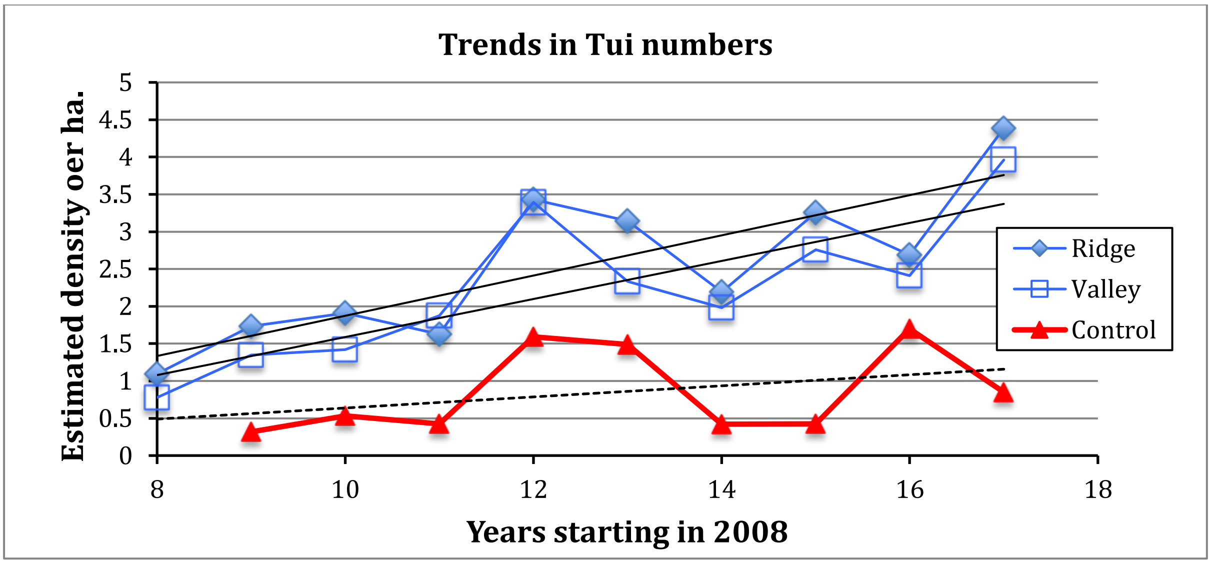


Fig 3. Trends in tui numbers between ridges and valleys, and the old control, over ten years. Linear trend lines significant unless shown dashed. [12]

The numbers of small insectivores show more annual fluctuations than do the larger long-lived species, but all three species (grey warbler, fantail, silvereye) generally exhibit larger numbers in the managed areas. Only silvereye shows a (non-significant) negative trend (reduction) in both managed and unmanaged areas. Grey warbler appears to have increased similarly in both the managed and control areas, although there is more variability in the unmanaged areas

A separate analysis was made of the Rosalie Bay (Managed) data for silvereye. In 2016 silvereyes had been observed pecking diphacenone baits attached to trees in this area, and there was concern over possible mortality. However, in this area silvereye was apparently more abundant in 2017 (mean density/ha. 3.4 ± 4.5 as opposed to 0.8 ± 1.1 in 2016) although in both years silvereyes were recorded at only two points on the Rosalie Bay transect. The apparently large difference beween years is definitely not significant ($p = 0.32$ t-test) due to the small sample size. Silvereye densities are hard to estimate due to the tendency of the birds to form loose mobile flocks.

The Taumata data, based on one transect in 2016 and two in 2017, are shown separately in Figs 4 and 5. Although it is too soon to reach any conclusions from the Taumata results, it

[12] Fig 3: WH 2017 data anal tui.xlsx; Fig 4: WH 2017 Fig 4 plus tau; Fig 5: WH 2017 Fig 5. xlsx

can be noted that bird numbers are generally intermediate between the managed and control areas at Windy Hill. But see also the more detailed analysis later in this report (p.19).

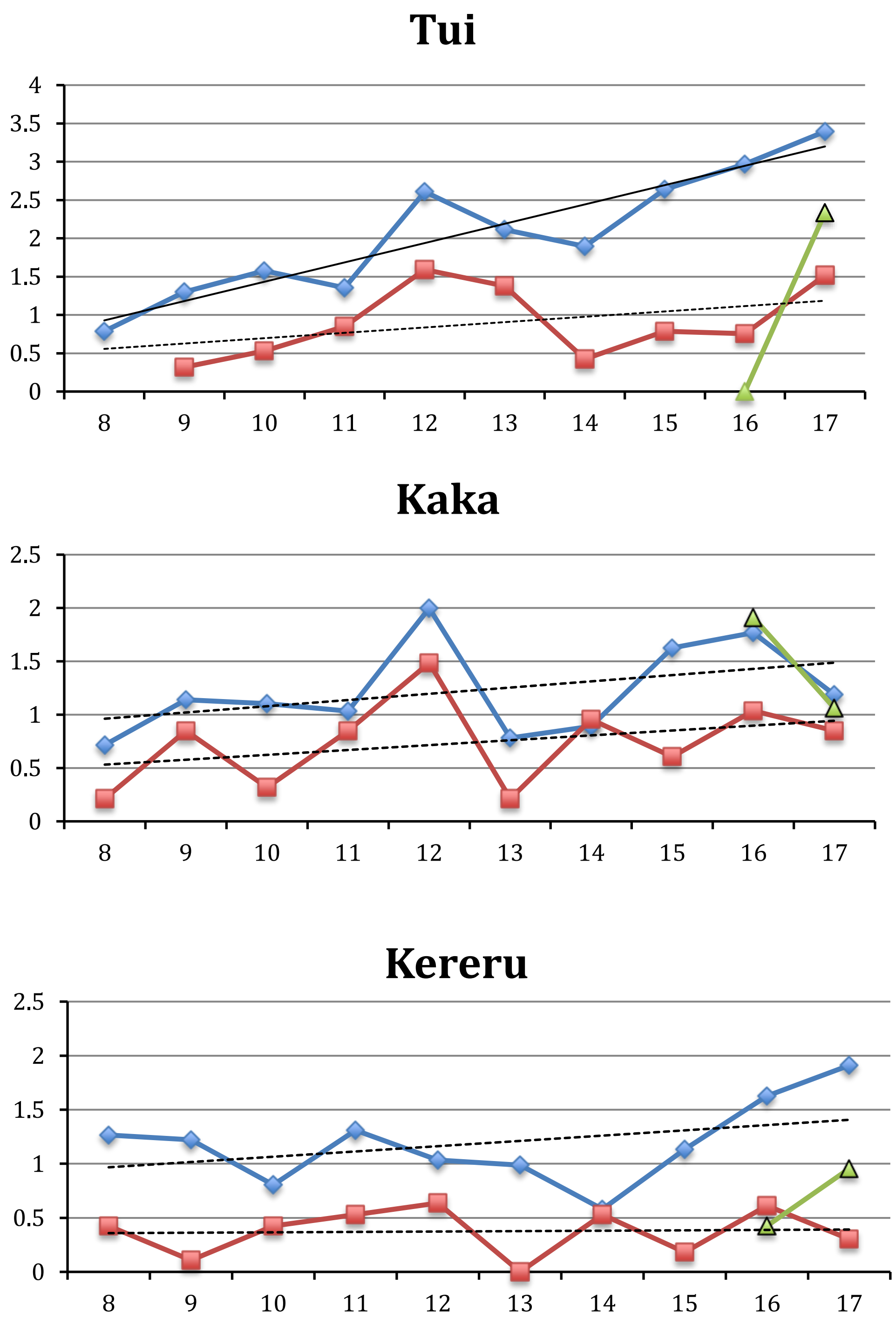


Fig 4. Trends in density/ha. for tui, kaka and kereru over 2008 – 2017. Managed areas indicated in blue, unmanaged in red. Taumata shown in green. Linear trend lines shown solid where statistically significant, otherwise dashed.

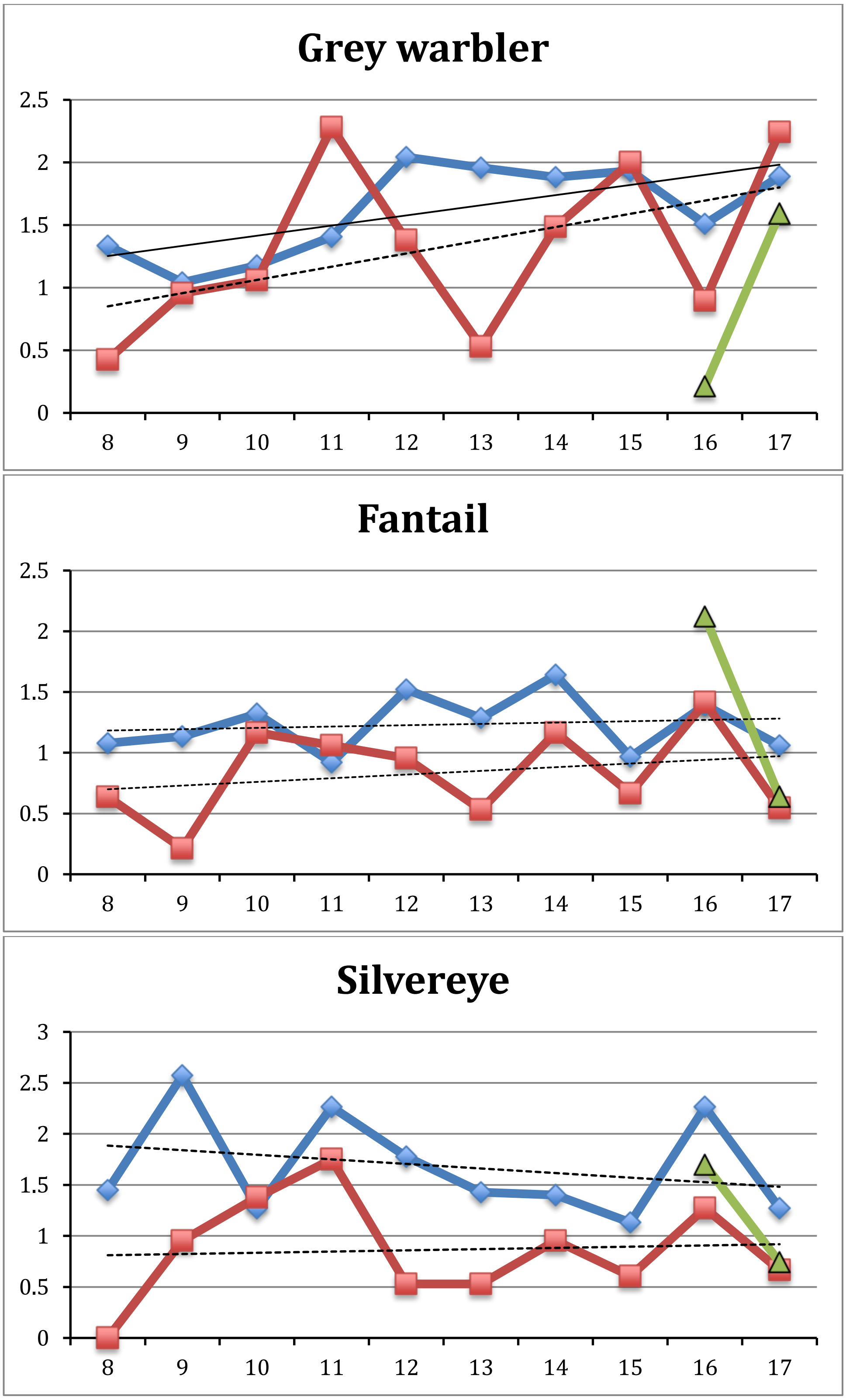


Fig 5. Trends in density/ha. for smaller insectivores over 2008 – 2017. Managed areas are indicated in blue, unmanaged controls in red, and the Taumata samples in green. Linear trend lines are shown solid where statistically significant, otherwise dashed.

Other species (Tables 6 & 7)

Table 6. Mean densities per 10 hectare for Shining Cuckoo, Kingfisher and 'others'.

Area	Year	Shining Cuckoo	Kingfisher	Other
Ridges	8	0	1	0
	9	1	5	4
	10	1	4	4
	11	2	7	6
	12	0	6	3
	13	1	4	6
	14	0	2	1
	15	2	4	1
	16	2	1	1
	17	1	1	3
Means, Ridges		1	3.5	2.9
Valleys	8	0	5	0
	9	0	8	1
	10	0	4	5
	11	1	11	2
	12	1	6	5
	13	1	11	4
	14	0	3	3
	15	1	8	1
	16	1	4	3
	17	0	6	5
Means, Valleys		0.5	**6.6**	**2.9**
Old Control	8	0	4	0
	9	0	2	0
	10	1	1	1
	11	2	4	5
	12	4	2	3
	13	6	4	0
	14	0	0	0
	15	0	0	0
	16	0	4	0
	17	0	0	2
Means, Old Control		1.3	2.1	1.1

Table 6 summarises density kingfisher, shining cuckoo and 'others' recorded in the 3-minute counts, over ten years. The only notable feature of these results is the generally greater abundance (conspicuousness) of kingfisher in Valley transects compared with Ridges and the Control. Shining cuckoo records are probably strongly influenced by the weather as the birds sing predominantly on sunny days, but overall this species is the only one which is apparently commoner in the controls compared to the managed areas – although the difference is not statistically significant and was entirely due to two years only (2012 & 13). However, grey warbler, the main host species of shining cuckoo, was *ranked* higher in the controls than in the managed area, which might account for the presence of cuckoos in the control site.

Detail for 'other species' in 2017 is given in Table 7. As in previous years, blackbirds were the most common 'other species' recorded. Conspicuousness due to song may be a factor. Chaffinches are also consistently present in small numbers. Overall, introduced passerines (especially blackbirds) could have increased slightly this year, but they are not frequent. The increased number of sparrows (3!), has also been noted anecdotally elsewhere on Great Barrier. Although sparrows were recorded in pre-2008 counts, they were not recorded again until 2015. Dunnock on the other hand was last recorded in 2011 and not since. It is a highly secretive bird on Great Barrier. It is noteworthy that Mynas, which invaded the area in 2011 but were then eliminated, have not re-appeared. Robins were introduced to Windy Hill in 2004, 2009 and 2012, and a few are still present, although this species has not been recorded in the December counts since 2013. Banded Windy Hill robins have been recorded on Hirakimata and elsewhere on Great Barrier since then. Bellbirds are heard occasionally, but have not been noted in the December counts since 2011. Some other species are present occasionally in the Sanctuary, such as long-tailed cuckoo, tomtit and red-crowned kakariki, with annual presence of brown teal (pateke) and black petrel, but none of these are represented in the December count data.

Table 7. Other species recorded. Figures in table are actual number of times the species was recorded

Area	Black bird	Chaffinch	Sparrow	Hawk	Banded rail	Morepork	Total Other
Ridges	3					1	4
Valleys	1	2		1	3		7
Benthorn	2		1	1			4
Robin	4	1				1	6
Taumata RB	3						3
Taumata Bush							0
Rosalie Bay	2		2				4
Control		1					1
Water Fall							0
Ros. Bay Rd	2						2
L. Goat Rd							0
Total	17	4	3	2	3	2	31

Other 'additional' marginal records (Table 8)

Birds heard or seen while moving between points were noted on the sides of the data sheets. This additional recording was not done in a consistent manner and was intended only to supplement the more carefully obtained data set already presented. 'Additional' counts in 2015 were adjusted in the controls by multiplying by 2.57 (i.e. 216/84) to allow for the lesser amount of time spent in the control areas. In 2016 much reduced numbers were counted between sample points, but this was due to the reduced number of observers available in that year. The 2015 and 2017 data, with the controls adjusted, are compared in Table 8. The species rankings are generally similar between years and areas, with the exception of kereru.

Kereru was the first or second species most commonly noted between sample points in the Sanctuary areas in both years, but it was one of the least frequently ranked in the Controls – it was not recorded at all in the Controls in 2017. This agrees with Fig 4, which shows that kereru is generally commoner in the managed areas, and in 2017 had a density in managed areas c. 4 times that of the controls. The ranking of the first three species (tui>kereru>kaka) as seen in these 'casual' observations in the Sanctuary is the same as that derived from the quantitative data, as it is also for the controls, where the low frequency of kereru agrees with its low frequency in the 3-minute control counts (Table 3).

Table 8. Number of times a bird was recorded as seen or heard while moving between count points in 2015 and 2017, and rankings. Three commonest species in each location and year are highlighted. Control numbers adjusted (x 3.1429) to allow for lesser amount of time spent in controls.

Species	Managed				Controls			
	2015		2017		2015		2017	
	Managed	rank	Managed	rank	Control	rank	Control	rank
Kereru	29	2	29	1.5	3	7	0	8.5
Tui	47	1	29	1.5	16	1	22	2.5
Kaka	28	3	24	3	10	2	28	1
kingfisher	13	5	15	4	5	5.5	13	4
Grey Warbler	11	6	13	5	8	3.5	22	2.5
Fantail	9	7	12	6	5	5.5	6	6
Shining Cuckoo	1	9	0	9	0	8.5	0	8.5
Silvereye	17	4	3	8	8	3.5	9	5
Other	5	8	8	7	0	8.5	3	7

Table 9. Rank correlation coefficients between species counted between sample points in Managed and Control areas in two years. The values in the Table are Spearman's Rank Correlation Coefficients. (Significance levels as in Table 4).

	Managed 2017	Control 2015	Control 2017
Managed 2015	0.8292(*)	0.7042	0.4583
Managed 2017		0.5083	0.4208
Control 2015			0.8875(*)

Ranks were compared with earlier rankings (2015; 2016 was not used due to much reduced effort in recording marginal birds in that year). Values of 0.8 as in Table 9 indicate a good agreement between the ranks, but are barely statistically significant ($p < 0.10$) due to the small sample sizes (n = 9 species, see Table 8). This analysis shows that within areas rankings agree between years, but rankings between managed and control areas do not agree, further emphasizing the significant differences between these areas established by the analysis of density data given in Table 6.

Changes in the Taumata block from 2016 – 2017

The 137 ha Taumata Pest Management Area, owned by Derek Bell, was added to the Sanctuary in 2016. In that year three sites were set up as controls (unmanaged), but became managed for rats in 2017. Consequently the difference over a single year gives an indication of the bird population responses (nesting success) after one year with a much reduced rat population.

Despite the overlapping Confidence Limits in Fig 6, the difference between the managed and unmanaged situations is close to being statistically significant using an unpaired 2-tailed t-test ($p = 0.058$ (*), n= 60 samples). The overall upwards trend is largely a result of statistically significant increases in tui ($p < 0.001$ ***) and grey warbler ($p < 0.01$ **). No other bird species shows a significant change in abundance (overlapping confidence intervals), but the apparent increase in kereru should be noted (Fig 7).

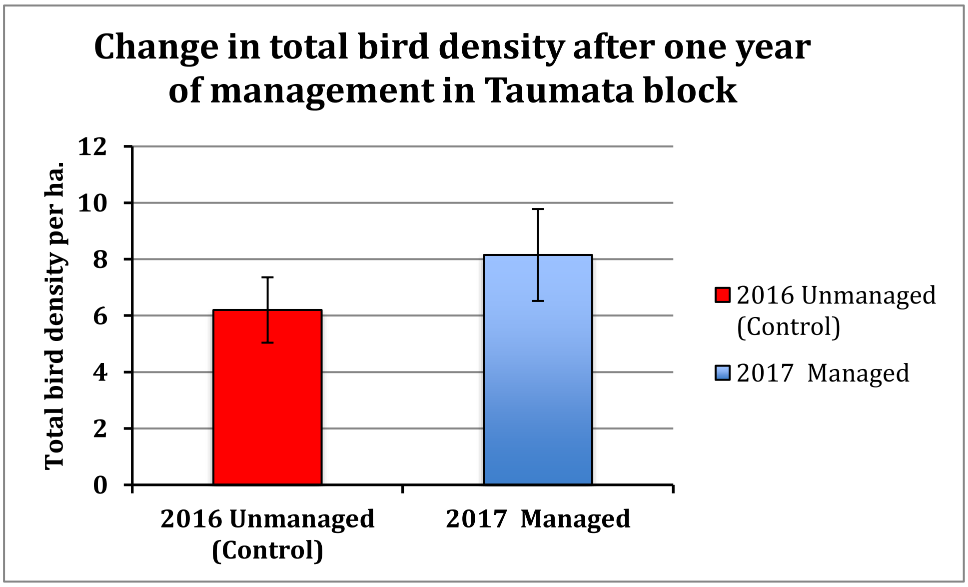


Fig 6. Total bird density with 95% Confidence Limits in the Taumata block before and after management; 2016 (Unmanaged), 2017 (Managed).

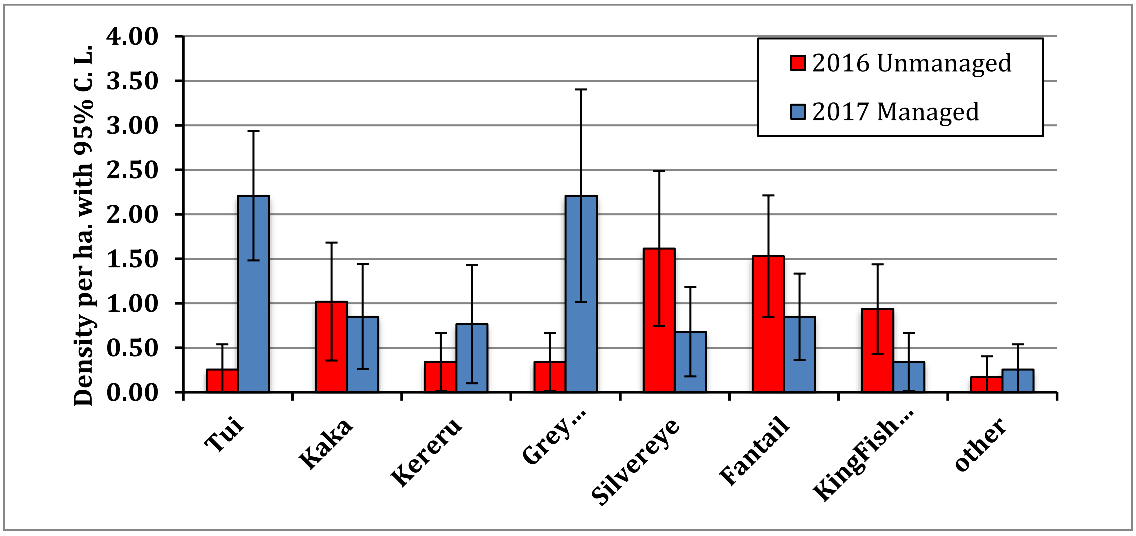


Fig 7. Bird densities before (red) and after (blue) one year of management in the Taumata block, with 95% Confidence Intervals.

Comparisons of overall bird abundance with rat abundance assessed by tracking tunnels (2008 – 2017).

Four lines of ten tracking tunnels (TTs) are monitored in the 'Little Windy Hill' area, equating to the Ridge and Valley transects used for birds. These TTs are monitored five times each year, so annual average % TT are based on 20 data points (One transect of 10 TTs gives one data point). Two TT transects are similarly monitored in the old Control area. The TT data has been collected in both areas since 2008. The results of a comparison between bird densities and annual average TT rates are shown in Figs 8 and 9 and Table 10 [13].

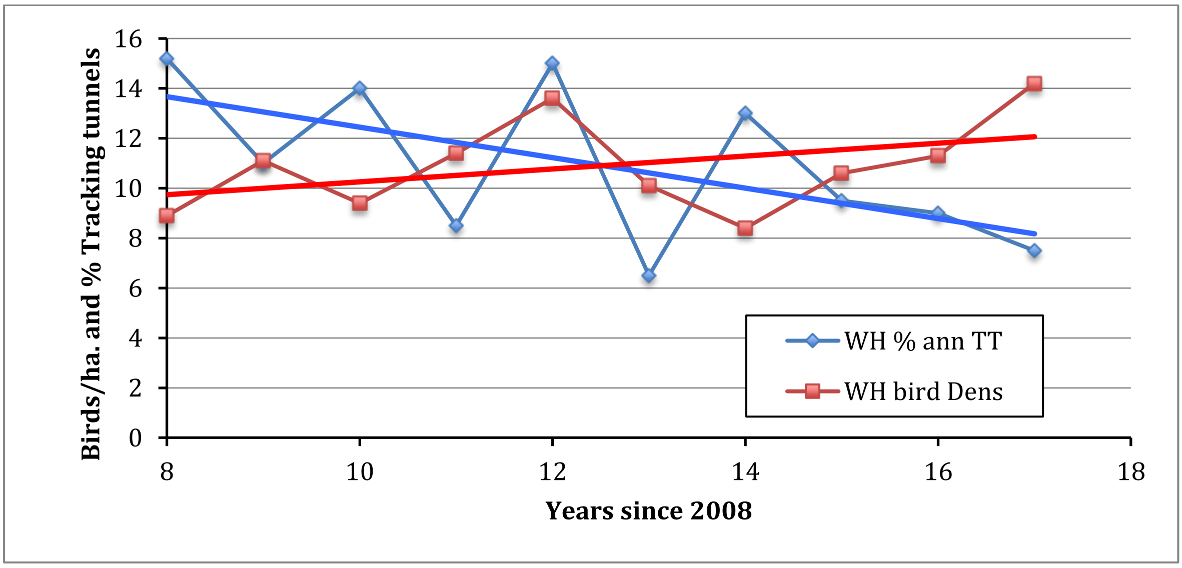


Fig 8. Trends in bird density and rat abundance (average annual tracking tunnel %s) in the Little Windy Hill area from 2008 – 17. Tracking tunnel data in blue, birds in red.

[13] Data for Figs 8 – 10 in: WH 2017 TTs Workbook WH v. CON fin. xlsx

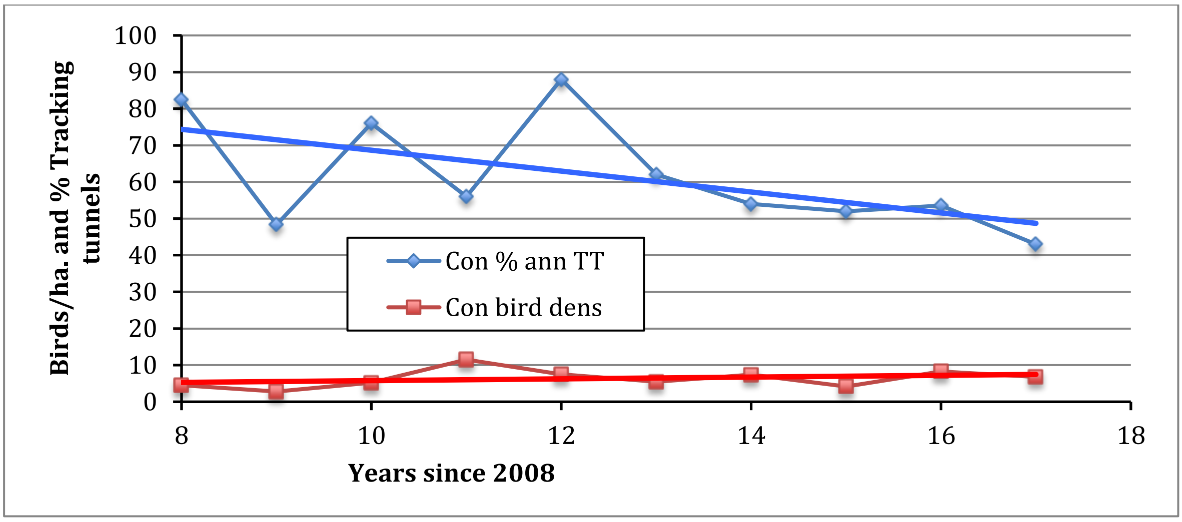


Fig 9. Trends in bird density and rat abundance in the old Control area (unmanaged) from 2008 - 17. Annual average tracking tunnel data in blue, birds in red.

Figure 8 demonstrates that the gradual decline in rats in the Little Windy Hill area (as monitored by the TTs) has been mirrored by an overall increase in birds. However, while the rat decline is almost statistically significant ($p < 0.10$), the bird increase is not (though it is if all the managed areas are considered together – e.g. in Fig 2 and Table 4). Similarly in the control, the rat decline is almost significant ($p < 0.10$) but the birds have increased only slightly (Fig 9; Table 10). This is presumably because although rat numbers have declined, they remain at a level inhibiting bird population increase.

Table 10. Correlation coefficients for trends in Figs 8, 9 and 10. Significance levels as in Table 5. NS, not significant.

Comparisons in figures	Correlation coefficient R	Degrees of freedom	Probability of correlation being due to chance P
Windy Hill rats v. years. (Fig 8.)	-0.5798	8	0.1 (*)
Windy Hill birds v. years. (Fig 8.)	0.4155	8	NS
Control rats v. years. (Fig 9.)	-0.5638	8	0.1 (*)
Control birds v. years. (Fig 9.)	0.2944	8	NS
Birds v rats Windy Hill. (no Fig.)	-0.308	8	NS
Birds v rats Control. (no Fig.)	-0.0529	8	NS
Birds v rats overall. (Fig 10.)	-0.6993	18	< .001 ***

Table 10 summarises the correlation data. Over the period 2008 – 17, rats (TT %s) have trended down in both managed and unmanaged areas, though levels remain much higher in the unmanaged control. The overall pattern of bird abundance and TT percentages is best illustrated by amalgamating the data from the managed and unmanaged areas. This is illustrated in Fig 10, showing generally higher bird densities where rat numbers are lower.

The overall correlation between rats and birds is negative and highly significant ($r = .6993$, $p < 0.001$. Table10, last line).

Figures 11 and 12 are other ways of demonstrating the difference in bird and rat abundances in the managed area compared to the unmanaged controls. The data are averaged over 10 years and the difference between the areas are very clear: if TT %'s are assumed to represent rat abundance, then there are c. 80% fewer rats in the sanctuary than in the Control site. Likewise the bird density data shows 70% more birds (all species) in the managed compared to the controls.

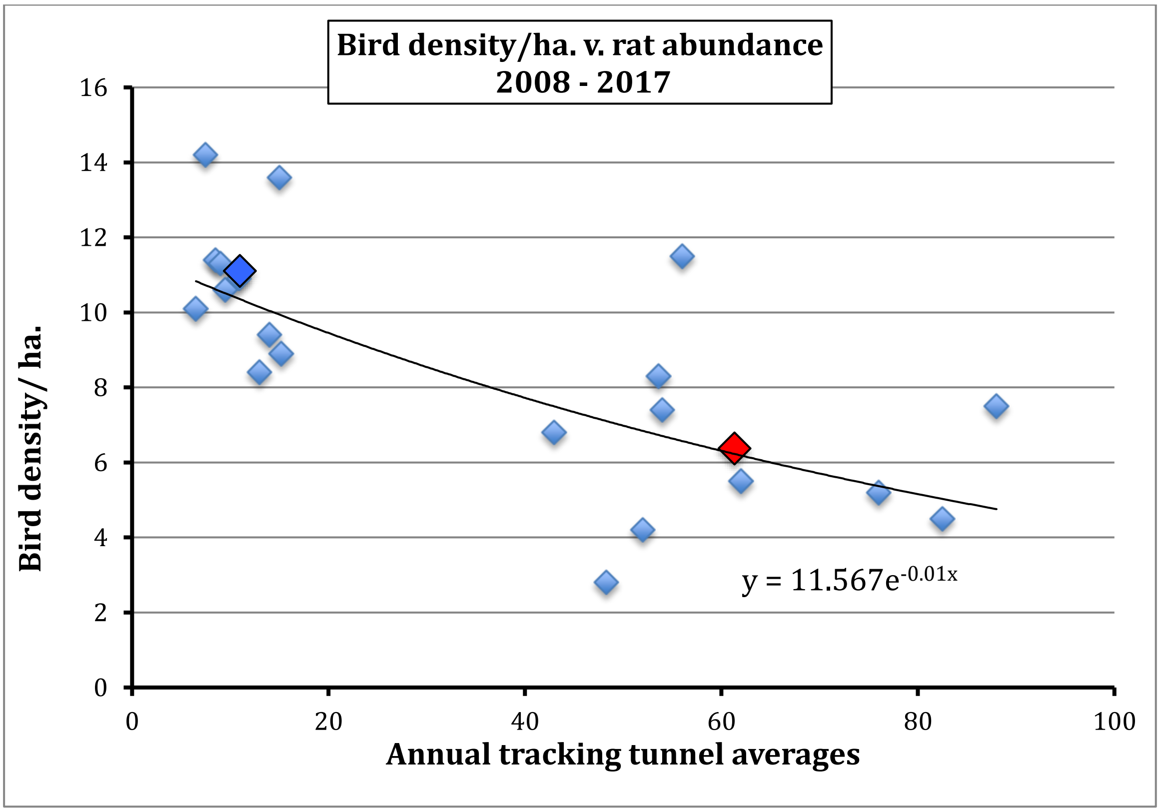


Fig 10. Relationship between bird abundance and TT %s (rat abundance). The data are annual means for 2008 – 2017. The larger blue marker is the overall mean for the managed area (LWH) and the red marker is the overall mean for the control data.

The difference between birds per ha in managed and unmanaged areas is an estimate of birds lost per ha in the unmanaged areas. This figure, based on the long-term averages (Fig 12b) is 4.5 birds/ha. This equates to 3465 birds saved over the current 770 ha being managed. Without relying too much on the actual number, it is clear that a substantial improvement in bird productivity is occurring in the managed area.

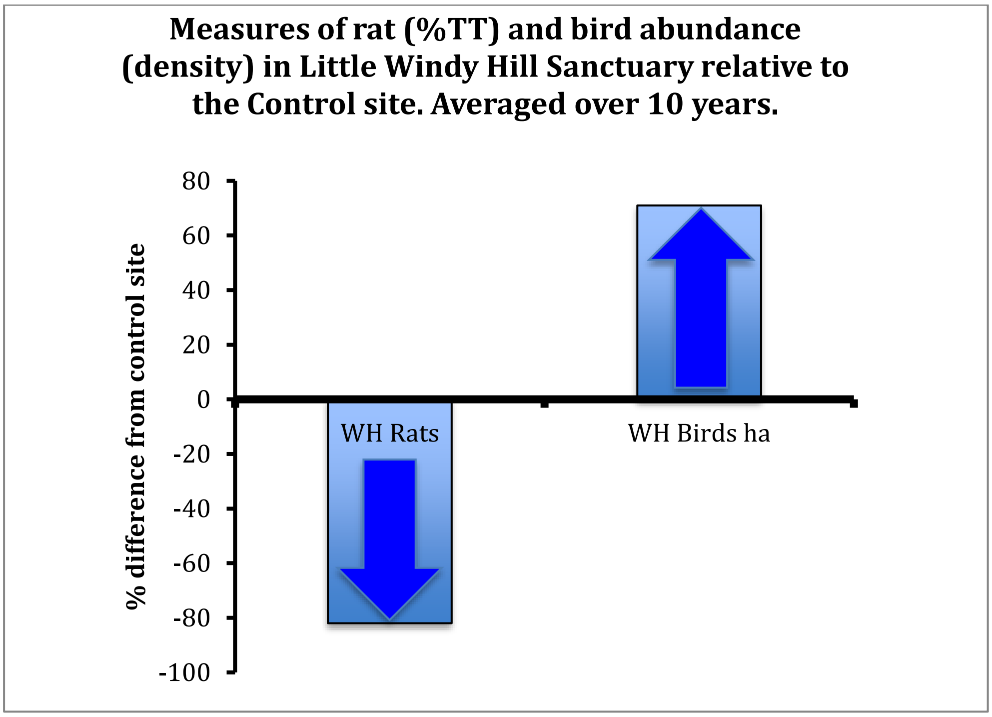
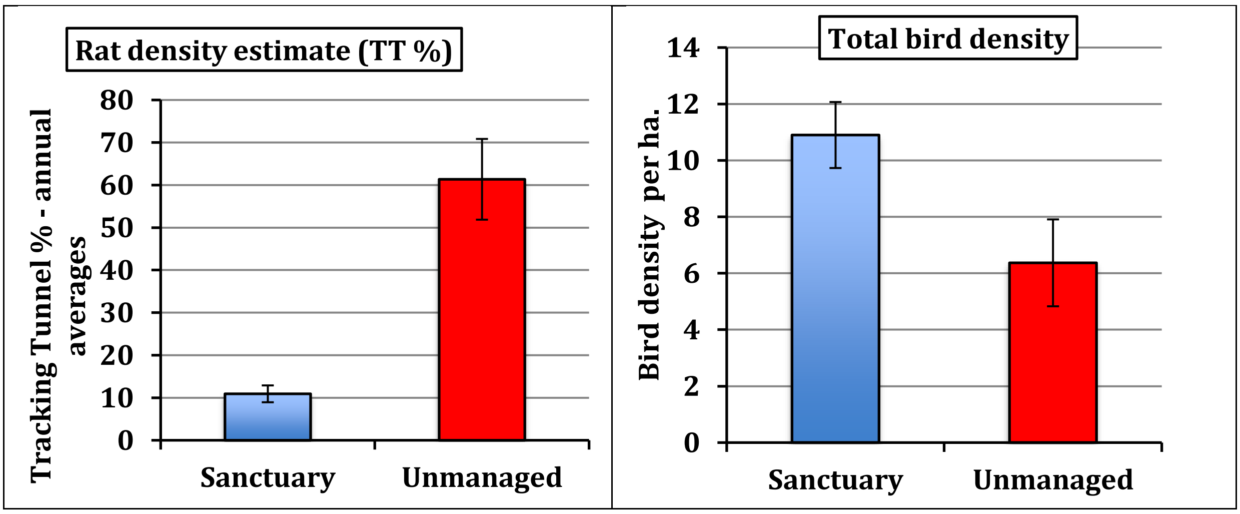


Fig 11. The Little Windy Hill (Ridge and Valley) TT and bird data compared with the Old Control data, all averaged over 2008 – 2017. Data are expressed as the % difference from the controls so that the horizontal line at zero represents the controls.



(a) ***(b)***

Fig 12 a, and b. The left figure (a) demonstrates significantly more rats in the unmanaged compared to the control areas (95% Confidence Limits based on 10 years of data). The right figure (b) demonstrates significantly more birds in the Sanctuary compared to the unmanaged control sites (95% C. L.;10 years data).

DISCUSSION

Much of the discussion in earlier Reports applies equally well to this, though here the longer-term trends and the correlations between bird abundance and %TT data (rat abundance) are dealt with in more detail. [The density estimates for individual species are probably best regarded as 'indices of abundance' rather than reliable estimates of actual numbers per hectare. Overall density (all species) is probably more robust, and is the best estimate of density per hectare available for birds in the bush on Great Barrier. As demonstrated previously[14] frequency and density are highly correlated, but because density utilises all the numerical and some of the distance data, and is not limited to a maximum of 100, it is the better comparative measure between years].

The long-term trend to increasing abundance of birds in the managed compared to unmanaged areas, is statistically reliable. This is particularly clear for tui, a result supported by other studies. An analysis of 5-minute bird counts from sites across the Auckland Region over a 6-year period (2009 – 2014: Ruffell, J. & Didham, R. K. 2017), suggests that tui and kereru show significant increases as a result of pest control measures. Overall species richness and abundance also increased with pest control, though this was largely driven by these two species. This positive effect of pest control is also seen in the Windy Hill data.

The 'obvious' interpretation of significant difference in levels of abundance and time-trends between the Sanctuary and Control areas is that they are a result of rat management in the Sanctuary. However it cannot be stated unequivocally that these trends are due to this management (rat reduction). This is the most likely reason, but the conclusion is confounded, because there are differences other than rat management between the managed and unmanaged areas; for example vegetation structure, sample times and sizes. Vegetation differences probably relate more to the relative sizes of trees in the control and management areas rather than to tree species composition[15], but it is hard to judge the significance of these differences from the bird's viewpoint – the factors influencing habitat choice by the different species. As every area of bush differs in some way from every other, there is no strict way around this problem. The 'solution' to this confounding is probably to increase the number of Control Areas, and ideally to have equal numbers of samples in both managed and controlled areas.

Despite annual differences in bird species abundance due to the vagaries of weather and food supplies, and the chance variations inevitably present where several different observers are involved, a statistically significant ten-year increase in species abundance in the Sanctuary has been demonstrated. Most of the overall Sanctuary increase is due to tui and grey warbler, but all species except silvereye have shown some increase and there are strong statistical differences between managed and unmanaged areas for all species except grey warbler. These significant density differences between managed and unmanaged areas at Windy Hill

[14] Windy Hill Rosalie Bay Catchment Trust. Bird Counts December 2012. P. 12. (Report JO 7. March 2013).
[15] Windy Hill Rosalie Bay Catchment Trust. Bird Counts December 2008. Report JO 1 February 2009.

may be some of the best data available illustrating the benefits of intensive pest reduction without total eradication.[16]

The Controls have also shown increases over time in abundance for all species, but none of these increases (even when summed as total for all bird species) are *statistically* significant trends. However, the consistent increases in the controls, coupled with other evidence of birds (e.g robins) moving out of Windy Hill to other areas, strongly suggests that the improved breeding success in the Sanctuary is ‘spilling over’ into adjacent areas. This is emphasised when a (previous[17]) conservative estimate of the number of birds saved from predation in the Sanctuary every year is considered: 2140. The same estimate based on the results in this report suggests the figure is now closer to 3500 birds saved over the larger 770 ha. area being managed. This implies that a substantial number of new young birds are being produced in the Sanctuary every year. A consequence must be that many of these birds seek new territories outside the Sanctuary, spilling over into the Control Areas, and adjacent unmanaged bush areas. The apparent increase in tui throughout Great Barrier may be fuelled by birds bred at Windy Hill (and presumably also in other managed areas, such as Glenfern Sanctuary).

The results from one year of management in the Taumata block suggest a significant increase in bird density, driven mainly by increases in tui and grey warbler. This could be due to increased breeding success within the Taumata block, but the speed of population increase suggests the increase might also be supplemented by birds spilling over from the other managed areas in Windy Hill.

Coincident with the reduction in rat numbers in the Sanctuary, there is also a reduction in rat numbers in the control areas. In contrast to the managed areas, the rat reduction in the controls is not yet sufficient to drive an internal (within control) bird improvement. Annual TT%s would need to drop to 30% (or less) before that might occur. The reasons for the decline of rats in the Control area are unknown, but it is conceivable that management in adjacent areas is reducing rat migration (just as it is increasing bird migration) into the Control Area. A gradual shift to more kiore compared to ship rat in the residual rat population is occurring, but if this is a factor it implies that kiore are less predatory, which is possible.

Silvereyes are generally in synchrony between controls and managed areas, though significantly more abundant in the latter. The analysis of the data from the Rosalie Bay transect (where silvereye were observed pecking diphacenone baits in trees in 2016) showed no significant difference between years and gives no cause for concern. It is unlikely that any such effect could be measured in a small area with such a mobile species unless it was very substantial.

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[16] Ruffell & Didham’s (3017) conclusion that the small insectivores are unresponsive to pest reduction (unless total eradication is achieved) is derived from complex modelling of the interactions between bird abundance, pest control (of unknown success) and forest cover.

[17] Windy Hill Rosalie Bay Catchment Trust. Bird Counts December 2015. P. 18. (Report JO 11 February 2016).

Since 2008 Grey Warblers have increased everywhere, including in the controls, where they show much variability in different years. As a consequence this is the only species not showing a significant (t-test; Table 4) difference between managed and control areas.

As concluded in earlier Reports, other evidence (e.g. reptile biomass) supports the conclusion of an improving ecosystem trend in the Windy Hill Sanctuary. This improvement may be partly driven by the natural forest succession, but keeping the controls in mind, it can be reasonably accounted for by the management regime having greatly reduced rodent populations in the managed areas. The results are a strong justification for continuing high intensity rodent control. An estimate of > 2000 birds saved by this work in the Sanctuary every year was presented in 2015.[18] The evidence presented in this report allows that estimate to be revised; based on the greater difference between managed and unmanaged areas and the increase in area managed, the current estimate is c.3500 birds saved annually over the 770 ha area.

CONCLUSIONS

° The ten years of records of bird abundance from the managed areas at Windy Hill, show positive trends for both frugivores and insectivores, with statistically significant positive trends for tui and grey warbler.

° The control areas may have benefitted from management in adjacent areas; not only has bird density apparently increased in them, but also rat numbers have declined.

° The decline in rat numbers since 2008 (TT%) in both managed and unmanaged areas approaches statistical significance ($p < 0.1$).

° Kereru shows no statistically significant increase over time, but are statistically more abundant in the managed area compared to the unmanaged.

° Grey warbler density has been increasing in both managed and unmanaged areas since 2008, but there is no statistically significant effect of pest control (i.e. no difference between managed and control areas)

° All species other than grey warbler are statistically more abundant in the managed areas compared to the unmanaged.

° The difference between rat-managed and unmanaged areas is unequivocal. Managed areas have almost twice as many birds, and more species, than unmanaged areas. Tui are c. 3 times as abundant in the managed areas and Kereru maybe 4 times.

° The difference between rat-managed and unmanaged areas in total bird abundance implies a total annual mortality of c. 4.5 birds per ha. in unmanaged areas. This can also be thought of

[18] Windy Hill Rosalie Bay Catchment Trust Bird Counts December 2015. Report JO 11 February 2016.

as a measure of potential 'unfilled space' in unmanaged areas into which birds can migrate from surrounding managed areas.

° Expressed as percentages, the Sanctuary has 70% more birds and 80% fewer rats, than the Control.

° The new area – Taumata – demonstrates the speed with which conservation gains can be made, with significant increases in tui and grey warbler over one year, and an overall gain when all species are considered together.

° There is no evidence that silvereye decline is associated with pecking toxin baits – rather it appears to be part of a longer-term pattern. Silvereye is statistically more abundant in the managed compared to the unmanaged area.

Important conclusions carried over from previous Reports:
° The difference between bird densities in managed and unmanaged areas allows an estimate of bird loss rate.
° When extrapolated to similar vegetation over the whole of Great Barrier this leads to the conclusion that c. 85,000 birds are being lost to rat predation every year.
° These conclusions draw attention to the value of monitoring long-term trends, which cut through the expected annual variability.

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RECOMMENDATIONS

1. That the current bird monitoring programme is continued in December each year.
2. That the current results are presented to all field workers at a meeting in April or May, and the field methodology reviewed with them in November.
3. That a new Control Area is designated, set up with tracking tunnels and monitoring commences in Dec 2018.

ACKNOWLEDGEMENTS

Thanks to the Foundation North for continued funding support. The field work was carried out by Rachel Wakefield, Henry Cookson, Dave Harland, Dean Medlands, Kevin Parker and Abby Naismith. This team was supervised by Judy Gilbert.

John Ogden. March 2018.
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APPENDICES

These data are the count and density data for each species at each count point. They are available in excel (.xlsx) files within the folders **WH 2017 RAW DATA** and/or **WH 2017 APPENDIX 1-2-3 Two** available from the author and submitted electronically with this report.

APPENDIX 1: Managed areas except Ridge and Valley Transects

These data are available in excel (.xlsx) files within the folder: WH 2017 RAW DATA accompanying the electronic version of this report.

Left side of each sheet, raw data as transcribed for analysis. Right side, density data.

Note that the values at the base of the left hand columns are (1) the count of cells with a number in the column, (2) the bird frequency, (3) the sum of numbers in the column. The numbers at the bases of the right hand columns are averages, standard errors and the 95% confidence interval.

APPENDIX 2: MANAGED AREAS – Ridges and VALLEYS

APPENDIX 3. CONTROLS