

Temporal changes in birds and bird song detected in Zealandia sanctuary, Wellington, New Zealand, over 2011-2015

BEN D. BELL

Centre for Biodiversity & Restoration Ecology, Victoria University of Wellington, New Zealand

Abstract Bird counts were carried out in Zealandia sanctuary, Wellington, New Zealand, along a 6.3 km slow-walk transect, every 3 weeks for 4 years (2011-2015). The mean \pm *se* number of species detected per count was 30.0 ± 0.4 (range 22-37) and the mean \pm *se* total of individuals detected per count was 572.7 ± 12.8 birds (range 361-809). Of 43 species detected, 15 occurred on every count, 8 on most, 13 less frequently and 7 only occasionally. Forest birds were mostly first detected by sound, but water or wetland birds mostly by sight. For 35 species with sufficient data to model, significant seasonal changes occurred in 9 species (26%) and significant annual changes in 4 species (11%), with the total of birds counted peaking in late summer/autumn. Song output varied amongst passerines, with large seasonal effects in 6 European introduced species, but lower seasonal effects in 9 native species.

Bell, B.D. 2015. Temporal changes in birds and bird song detected in Zealandia sanctuary, Wellington, New Zealand, over 2011-2015. *Notornis* 62 (4): 173-183.

Keywords transect-counts; conspicuousness; seasonality; introductions; bird song

INTRODUCTION

Relatively recent initiation of mainland island sites constitutes an important step in ecosystem-focused restoration goals being pursued in New Zealand (Saunders & Norton 2001; DOC 2015). However, there have been few studies of the entire bird communities that these sites support, nor of temporal patterns of change in such communities. Systematically repeated counts of birds allow documentation of temporal patterns of change in bird detections, such as annual and seasonal variation, although they do not unravel

the interplay between the birds' conspicuousness and their actual numbers (Gibb 1996; Sullivan 2012). Regularly repeated counts also provide opportunities for investigating temporal changes in bird behaviour, such as seasonal patterns of song output in passerines. The Zealandia sanctuary (hereafter 'Zealandia') in Wellington provided such an opportunity for repeated counts, including species translocated there as part of restoration management, and a range of introduced species (Zealandia 2012).

Seasonal patterns of change in the forest avifauna of New Zealand have been variously reported (Dawson *et al.* 1978; Brockie 1992; Freeman 1999; Gibb 1996; Smith & Westbrook 2004;

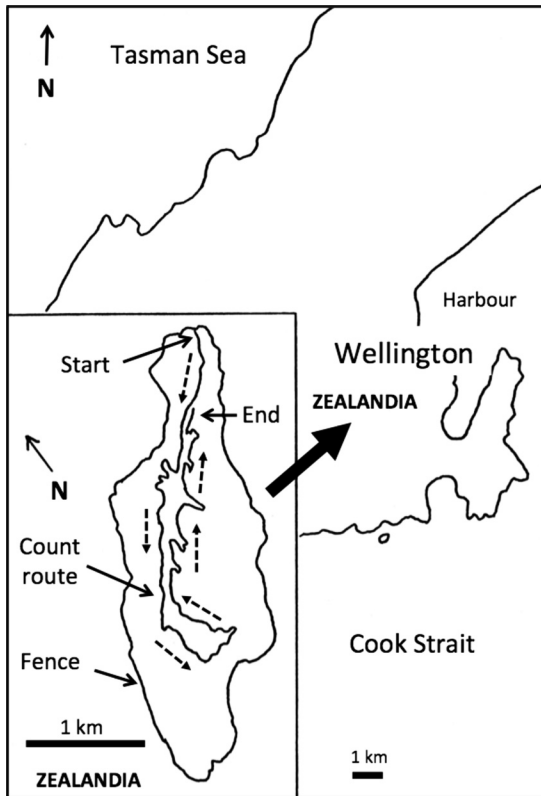


Fig. 1. Location of the study site at Zealandia. Inset shows the count transect-route, dashed arrows indicating the direction.

Azar 2012; Sullivan 2012). For example, Brockie (1992) described seasonal fluctuations of birds in the Orongorongo Valley forest near Wellington, and Gibb (1996) recorded proportions of birds either first seen or first heard there, noting their relevance for interpretation of bird counts. More recently Azar (2012) counted 16 forest species each month for a year in Zealandia, noting again that vocal activity varied seasonally, affecting conspicuousness.

Tomkins (2012) introduced a wide range of approaches to monitoring bird populations in New Zealand, aiming to inform the debate around the pros and cons of implementing different bird monitoring techniques. Most indices for monitoring forest birds in New Zealand have used the 5-minute point count method of Dawson & Bull (1975), reviewed by Hartley (2012), and also being undertaken by the Ornithological Society of New Zealand in Zealandia (C. Miskelly, *pers. comm.*). Another method, used in the present paper, is the slow-walk transect count of all species, in which count data are collected continuously, and not at

intervals, while the observer walks at a slow pace to ensure a high detection probability (O'Donnell 1996; Handford 2002; Spurr 2005; Morgan *et al.* 2012; Sullivan 2012).

This study aimed to document temporal patterns of change in bird species detected by day in Zealandia, and the seasonal song patterns amongst passerine species there, including native and introduced European species with different evolutionary histories and acoustic partitioning (Azar & Bell, *in press*).

METHODS

Study site

The study site at Zealandia is a 225 ha reserve within Wellington city ($41^{\circ}17'5.9''S$, $174^{\circ}44'39.5''E$), protected since August 1999 by an invasive mammal-proof boundary fence 8.6 km long and 2.2 m high (Campbell-Hunt 2002; Warne 2002; Zealandia 2014). All invasive mammalian predators and herbivores were exterminated there (except house mouse *Mus musculus*) and 15 native bird species have been translocated to the sanctuary, most successfully establishing (Miskelly *et al.* 2005; Taylor *et al.* 2005; Bell 2010; Zealandia 2012; Empson & Fastier 2013). Zealandia comprises a valley with steep-sided gullies and primarily native lowland podocarp-broadleaf forest (Campbell-Hunt 2002; *pers. obs.*), leading down to 2 dammed former water storage lakes with low-lying or wetland areas at the shallow ends. The area is accessed by a road (Lake Road) included in a network of 32 km of walking tracks (Zealandia 2014).

Bird counts

The slow-walk transect count procedure to detect birds in Zealandia was adapted from that first used by the author to detect seasonal trends in forest birds in the Orongorongo Valley, east of Wellington, in the 1970's (Bell 1972; Brockie 1992). On mostly fine, dry, calmer days, 72 transect counts were completed by the author from 1 August 2011 to 27 August 2015, along the same route at about 3 week intervals ($x = 20.8$ days, $se = 0.9$ days, $n = 72$). The August 2011 start date allowed 2 preliminary trial counts that month, then from September the inclusion of the full breeding season over the austral spring and summer. The count start time was based on the opening time of Zealandia (10.00 h). For about half of the year (late September-early April) NZ Daylight Saving Time applied, so effectively counts during that period were an hour earlier than at other times of the year. Starting at the entrance to Zealandia, the transect count route involved a slow walk that covered a 6.3 km circuit that included Lake Road to the south of the Lower Karori Reservoir, past

the wetland to Te Mahanga Track, Lynch Track, Swamp Track, northern end of Upper Reservoir, Discovery Area, Rock Dam Track, Round the Lake Track (W), Faultline Track, Tui Glen Track, Turbine Track, Round the Lake Track (E), Suspension Bridge Track, Karearea Track, Union Mine Track (short), Tui Terrace, and Lake Road to gate near Tuatara Nurseries (Fig. 1).

All birds seen and/or heard were recorded, and for each record the species identified, and for passerines, whether the bird was heard to sing (from September 2011), following Gibb (1996). Unidentified records were omitted, but were few. Names of species are based on Gill *et al.* (2010), with most scientific names given in Table 1. As the topography of the count route included open lakes and a wetland, plus forest ridges and valleys, sustaining an accurate and constant distance for a count zone either side of the observer was problematical, so all birds distinctly seen or heard were included in the count, and this was mostly within 50 m either side of the observer in forest. Counts included birds seen on the lake and those flying overhead. Every effort was made to avoid multiple counts of an individual, although in more mobile species individuals might have been counted more than once. Statistical tests were done in IBM SPSS Statistics for Macintosh, Version 22.

RESULTS

Summary of counts

The mean ($\pm se$) duration of the 72 counts was 203.6 \pm 1.7 m, at a mean ($\pm se$) walk speed of 1.9 km \pm 0.02 km·h⁻¹. Over the 4 years, 43 species were detected, this total being reached by November 2014. The mean number of species ($\pm se$) detected per count was 30.0 \pm 0.4 species (range 22-37), while the mean ($\pm se$) total of individuals detected per count was 572.7 \pm 12.8 birds (range 361-809).

Fifteen species were recorded on every count (mallard, New Zealand scaup, pied shag, kaka, North Island saddleback, stitchbird, grey warbler, bellbird, tui, whitehead, New Zealand fantail, North Island robin, silvereye, Eurasian blackbird, and chaffinch). Eight other species were recorded on most (>80%) of the counts (red-crowned parakeet, dunnoek, brown teal, South Island takahe, eastern rosella, New Zealand pigeon, European greenfinch, and house sparrow), while a further 13 species were less frequent (30-80% of counts: paradise shelduck, little shag, southern black-backed gull, common starling, black shag, song thrush, European goldfinch, New Zealand kingfisher, California quail, New Zealand falcon, little black shag, welcome swallow and shining cuckoo [*Chrysococcyx lucidus*]). Finally, 7 species were detected only occasionally (New Zealand dabchick [*Poliiocephalus*

rufopectus], pukeko [*Porphyrio melanotus*], morepork [*Ninox novaeseelandiae*], common redpoll [*Carduelis flammea*], yellowhammer [*Emberiza citrinella*], swamp harrier [*Circus approximans*] and long-tailed cuckoo [*Eudynamis taitensis*]).

The highest (mean $\pm se$) number counted were: whitehead (97.7 \pm 2.3) birds, followed by silvereye (62.1 \pm 7.9), tui (60.7 \pm 2.7), Eurasian blackbird (44.0 \pm 1.9), North Island robin (39.5 \pm 2.2), North Island saddleback (35.3 \pm 0.9), mallard (28.7 \pm 1.8), kaka (28.6 \pm 1.1), grey warbler (26.3 \pm 1.7), stitchbird (23.4 \pm 0.8) and pied shag (22.4 \pm 1.2). The generally larger water or wetland birds of open habitats, such as waterfowl, shags, gallinules and gulls, were mostly first detected by sight, as was welcome swallow. In contrast, most forest or scrub species were first detected by hearing them (*e.g.*, shining cuckoo, grey warbler, eastern rosella, silvereye, song thrush, New Zealand fantail and North Island saddleback; Appendix 1).

Temporal patterns of change

Mean seasonal and annual counts for each species are shown in Appendix 1. A negative binomial generalised linear model was used to model bird counts individually for 35 species with season and seasonal year (September-August) as categorical predictors (Table 1). Eight species were excluded due to insufficient records which meant that some convergence criteria were not met and the validity of the model fit was uncertain. Amongst these was the shining cuckoo, a spring and summer migrant to Zealandia, that clearly had a seasonal pattern (Appendix 1).

Overall, most birds were detected in the autumn or summer, fewer in spring, with lowest counts in winter (Appendix 1). For 9 species there was a significant seasonal effect ($P < 0.05$) after applying the Benjamini-Hochberg test for multiple comparisons (Benjamini & Hochberg 1995). The most marked seasonal effects ($P < 0.001$) occurred in the kingfisher, silvereye and common starling, moderate seasonal effects ($P < 0.01$) occurred in little shag, little black shag, southern black-backed gull, welcome swallow and European goldfinch, with a lower but significant seasonal effect ($P < 0.05$) in eastern rosella (Table 1).

For 4 species there was a significant annual effect ($P < 0.05$). The most marked annual effects ($P < 0.001$) occurred in the North Island fantail and house sparrow, while moderate annual effects ($P < 0.01$) occurred in the welcome swallow and European greenfinch (Table 1). For most species there was no significant annual effect ($P > 0.05$). Over the 4-year count period, the direction of annual differences in mean numbers counted indicated increases in some species (*e.g.*, fantail and house sparrow; Appendix 1).

Table 1. Seasonal and annual effects on bird counts in Zealandia using a negative binomial generalized linear model, with count as the dependent variable, season and seasonal year (September-August) as categorical predictors. Less common species are omitted. Significant P values, after applying the Benjamini-Hochberg (1995) procedure, are shown in bold.

Species	Season			Year		
	χ^2	df	P	χ^2	df	P
California quail (<i>Callipepla californica</i>)	9.428	3	0.024	1.787	3	0.618
Paradise shelduck (<i>Tadorna variegata</i>)	10.109	3	0.018	3.530	3	0.317
Brown teal (<i>Anas chlorotis</i>)	4.030	3	0.258	1.424	3	0.700
Mallard (<i>Anas platyrhynchos</i>)	2.550	3	0.466	2.502	3	0.475
New Zealand scaup (<i>Aythya novaeseelandiae</i>)	1.895	3	0.594	6.688	3	0.083
Little shag (<i>Phalacrocorax melanoleucos</i>)	17.191	3	0.001	3.063	3	0.382
Black shag (<i>Phalacrocorax carbo</i>)	7.807	3	0.050	11.896	3	0.008
Pied shag (<i>Phalacrocorax varius</i>)	0.504	3	0.918	6.146	3	0.105
Little black shag (<i>Phalacrocorax sulcirostris</i>)	14.671	3	0.002	11.612	3	0.009
New Zealand falcon (<i>Falco novaeseelandiae</i>)	2.272	3	0.518	2.206	3	0.531
South Island takahe (<i>Porphyrio hochstetteri</i>)	1.358	3	0.715	0.233	3	0.972
Southern black-backed gull (<i>Larus dominicanus</i>)	13.453	3	0.004	2.543	3	0.468
New Zealand pigeon (<i>Hemiphaga novaeseelandiae</i>)	1.954	3	0.582	10.719	3	0.013
North Island kaka (<i>Nestor meridionalis</i>)	0.862	3	0.835	0.720	3	0.868
Eastern rosella (<i>Platycercus eximius</i>)	11.339	3	0.010	2.831	3	0.418
Red-crowned parakeet (<i>Cyanoramphus novaeseelandiae</i>)	3.423	3	0.331	6.364	3	0.095
New Zealand kingfisher (<i>Todiramphus sanctus</i>)	18.099	3	<0.001	1.959	3	0.581
North Island saddleback (<i>Callaeas wilsoni</i>)	0.586	3	0.900	0.186	3	0.980
Stitchbird (<i>Notiomystis cincta</i>)	0.852	3	0.837	0.627	3	0.890
Grey warbler (<i>Gerygone igata</i>)	9.075	3	0.028	0.121	3	0.989
Bellbird (<i>Anthornis melanura</i>)	2.311	3	0.510	3.034	3	0.386
Tui (<i>Prothemadera novaeseelandiae</i>)	1.471	3	0.689	0.157	3	0.984
Whitehead (<i>Mohoua albigilla</i>)	0.119	3	0.989	0.561	3	0.905
New Zealand fantail (<i>Rhipidura fuliginosa</i>)	4.286	3	0.232	22.237	3	<0.001
North Island robin (<i>Petroica longipes</i>)	8.744	3	0.033	0.062	3	0.996
Silvereye (<i>Zosterops lateralis</i>)	52.474	3	<0.001	4.010	3	0.260
Welcome swallow (<i>Hirundo neoxena</i>)	17.328	3	0.001	15.962	3	0.001
Eurasian blackbird (<i>Turdus merula</i>)	2.592	3	0.459	0.428	3	0.934
Song thrush (<i>Turdus philomelos</i>)	4.435	3	0.218	3.183	3	0.364
Common starling (<i>Sturnus vulgaris</i>)	20.856	3	<0.001	10.059	3	0.018
House sparrow (<i>Passer domesticus</i>)	5.594	3	0.133	30.843	3	<0.001
Dunnoek (<i>Prunella modularis</i>)	7.294	3	0.063	2.784	3	0.426
Chaffinch (<i>Fringilla coelebs</i>)	9.001	3	0.029	1.281	3	0.734
European greenfinch (<i>Carduelis chloris</i>)	9.883	3	0.020	15.828	3	0.001
European goldfinch (<i>Carduelis carduelis</i>)	13.230	3	0.004	10.406	3	0.015

Table 2. For each passerine species studied in Zealandia over 2011-2015, a χ^2 test of independence was used to determine whether or not a bird was in song is independent of season. Species are ordered by the strength of seasonal difference measured using Cramér's *V* statistic. Values for introduced species in **bold** show a large seasonal effect, remaining native species show medium seasonal effects. Guidelines at 3 *df* for effect sizes for *V* are 0.06 = small, 0.17 = medium, 0.29 = large (Cohen 1988).

Species	χ^2	<i>df</i>	<i>P</i>	Cramér's <i>V</i>
Tui	35.57	3	<0.001	0.09
North Island robin	47.19	3	<0.001	0.13
Silvereye	96.41	3	<0.001	0.15
Stitchbird†	53.37	3	<0.001	0.18
North Island saddleback*	93.83	3	<0.001	0.19
Bellbird	31.58	3	<0.001	0.20
Whitehead	327.10	3	<0.001	0.22
Grey warbler	113.35	3	<0.001	0.25
New Zealand fantail	51.84	3	<0.001	0.25
Song thrush	9.77	3	<0.05	0.30
Common starling	32.40	3	<0.001	0.34
European greenfinch	36.13	3	<0.001	0.37
Chaffinch	197.07	3	<0.001	0.42
Eurasian blackbird	629.72	3	<0.001	0.45
Dunnoek	747.09	3	<0.001	0.69

†male whistle call; * includes chatter song

Seasonal passerine song output

The pattern of mid-morning to early-afternoon song output detected in passerines ranged from marked seasonality in some species (most song in austral spring and summer) to some song output throughout the year in others. However, all 15 species for which there were song data showed significant seasonal heterogeneity ($\chi^2 = 9.77$ to 747.09 , *df* = 3, *P* = < 0.05 to < 0.001; Table 2). Differences between song seasonality in native and introduced species were evident when the species' data were ordered according to the strength of seasonal heterogeneity using Cramér's *V* statistic (Cramér 1999; Cohen 1988). Nine native species showed medium seasonal effects, but seasonal effects were large in all 6 introduced species (Table 2).

While song output was often restricted to territorial males, typical of many passerines (Catchpole & Slater 2008), the context and type of song varied between species, and vocalisations were more difficult to classify as song in some. In the grey warbler, male song output was distinct and peaked in the spring, though song was heard at other times of the year, while in the North Island robin, male song peaked over late summer/autumn (Fig. 2). In the whitehead, comparatively few birds

sang, mostly during spring and summer, though detections from flock calling were audible and widespread throughout the year (Appendix 1). In the silvereye relatively few were detected in song (Fig. 2), but there was strong seasonality (Table 1) due to large numbers detected in the autumn (Appendix 1).

The North Island saddleback has a loud chattering call uttered throughout the day, while territorial males sing male rhythmical song characterised by 2-4 introductory chips followed by a series of highly stereotyped and repeated phrases (Parker 2013). For the present analysis, both chatter calls and rhythmical song are included as 'song' and its detection occurred throughout the year (Fig. 2), though rhythmical song (not differentiated here) occurred mostly during the breeding season. In both tui and bellbird song included defence of food resources, tui singing throughout the year with the smallest seasonality effect (Table 2), while in the bellbird increased song was detected in spring and summer (Fig. 2; Table 2). Male fantail song was also heard through the year, but again was more evident in spring and summer (Fig. 2). Male stitchbirds emit variants of a whistle call with 2-3 notes, but do not utter a full song as such, though both sexes warble (Castro

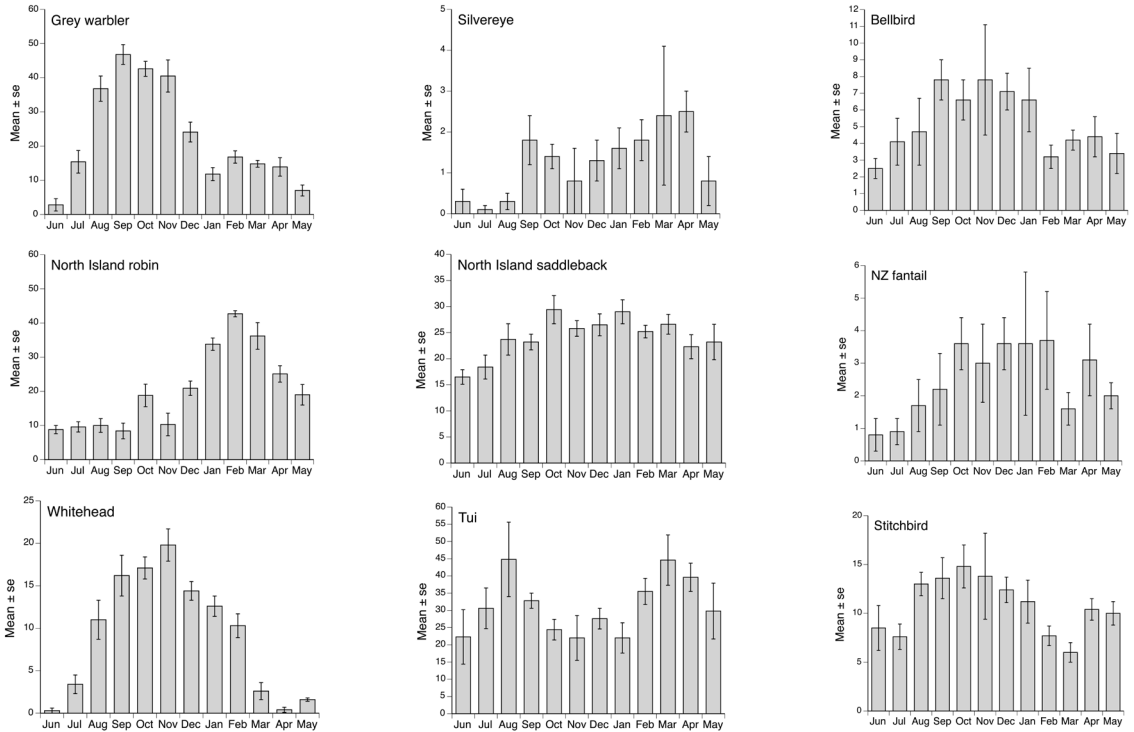


Fig. 2. Mean song output per count for each month in 9 native passerines counted over 2011–2015. The bars show mean (\pm se) number of individuals that sang. The year runs from June–May to cover the period through to the breeding season. Song includes chatter calls in the saddleback and represents male advertisement calls in the stitchbird.

2013), so for this species, the seasonality of these male whistle call detections, rather than warbles or song *per se*, was investigated, and showed a spring/summer increase (Fig. 2; Table 2).

The song periods detected in 6 introduced European species were mostly during the breeding season (Fig. 3), except the starling where more singing males were heard in the autumn (Fig. 3). The strength of the seasonal effect on song output was large for all these introduced passerines, in contrast to native species (Table 2).

DISCUSSION

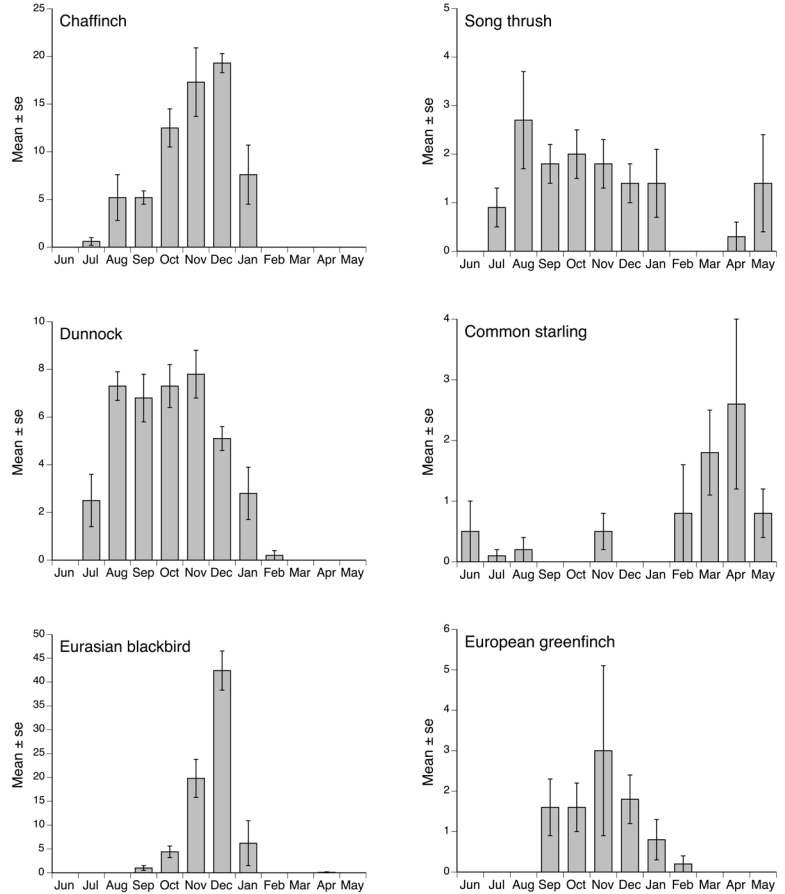
Bird counts are undertaken for a wide variety of reasons using a range of methods (Verner 1985; Bibby *et al.* 1992, 1998; Gibbons *et al.* 1996; Sutherland 2000; Tomkins, 2012). Species detection rates vary according to species’ conspicuousness, which in turn relates to such factors as size, colouration and behaviour, while counting error and counting bias may occur (Krebs 1999). Gibb (1996) noted that if vocalisations account for much of the seasonal variation in conspicuousness, then seasonal patterns of song increase detectability of some species at certain times of year, rather than counts representing

changes in abundance. This is important if density estimates are required, but in this study the emphasis was not on monitoring numbers *per se*, but simply to document temporal patterns in bird detections on repeated transects. This also relates directly to bird species that visitors to Zealandia might detect at different times of the year.

Some recorded changes in detection are likely to reflect actual changes in abundance. For example, in the New Zealand fantail there was a highly significant year effect ($P < 0.001$, Table 1). Thirteen birds were detected on the first count (1 August 2011), declining to only 2 birds for the next 5 counts, with a mean \pm se of only 4.2 ± 0.7 birds over the first seasonal year, that increased to 18.1 ± 1.9 birds by the fourth seasonal year (Appendix 1). The initial decline followed severely cold weather conditions later in August 2011 (McDavitt 2011). Wellington bird banders also noted a large reduction in numbers of fantails caught then, probably due to the winter snow (Reese 2012), and the species’ susceptibility to cold weather is well known (Powlesland 2013).

An early decline in detections of bellbirds also occurred after the first count, also possibly reflecting a local decline in numbers, and that count

Fig. 3. Mean song output per count for each month in 6 introduced passerines counted over 2011-2015. The bars show mean (\pm se) number of individuals that sang. The year runs from June-May to cover the period through to the breeding season.



followed a recent translocation. Detections of house sparrows increased over the years, again probably reflecting changes in abundance. The reintroduction of red-crowned parakeets in 2010 (Zealandia 2014) provided feeding stations of millet seed, probably leading to increased counts of house sparrow, as well as European greenfinch, attracted to the seed (Table 1; Appendix 1).

Overall, the most detected species in Zealandia was the whitehead, but despite this, only one long-tailed cuckoo, a brood parasite of whitehead, was detected (Appendix 1). In time, this cuckoo might increase its brood parasitism of whitehead at Zealandia, now that the species has been successfully reintroduced there. A marked seasonal increase in detection rate occurred in the silvereye, which flocked in late summer/autumn (Table 1; Appendix 1), as observed in the Orongorongo Valley (Brockie 1992; Gibb 1996, 2000), and elsewhere in New Zealand (*e.g.*, Dawson *et al.* 1978).

Counts in this study started relatively late in the morning, so for some species at least, song output would be less than at the dawn and dusk

song peaks typical of passerines (Catchpole & Slater 2008). For example, Eurasian blackbirds in Wellington commenced singing at dawn and dusk from July (*pers. obs.*), but were not detected singing on morning counts until September-October, peaking in December (Fig. 3). A case of late autumn song of the Eurasian blackbird was recorded in mid April 2014, also reported in Europe for this species (Alexander 1938; Cramp *et al.* 1988).

The effect of season on song output was clearly greater for 6 introduced passerines (Table 2). For most there was a distinct breeding season increase in song detections (Fig. 3), following absence of song detection during the winter, in contrast to many native passerines that sang through much of the year, though again often with a song increase during the breeding season (Fig. 2). Starlings were heard singing, mostly in autumn, but were apparently visitors to the sanctuary, so the song pattern recorded (Fig. 3) may be an artifact representing only part of their annual song cycle, which in Europe extends for much of the year (Alexander 1938; Cramp *et al.* 1994).

The more restricted song periods of the other introduced passerine species reflect their main song periods in Europe (Alexander 1938), where ancestral populations would have had to adapt to harsher winters, often with movement away from breeding areas to seek food resources (e.g., Cramp *et al.* 1988, 1994). To match southern hemisphere seasons, these introduced European species have of necessity adjusted their annual cycles, such as timing of song, breeding and moult. Their song may also have diverged to some degree, for example in the song thrush (Azar 2012) and chaffinch (Jenkins & Baker 1984), while in Zealandia chaffinch even sing from the ground on occasion (Bell 2006), a trait unusual in Europe (Witherby *et al.* 1938).

In Lower Hutt, Gibb (2000) also recorded song mostly in the breeding season in Eurasian blackbird, chaffinch and European goldfinch, but this was less evident in the dunnock. He found more extended song periods for song thrush and silvereye, and song throughout the year for grey warbler, common starling and Australian magpie. The New Zealand fantail and tui vocalised throughout the year, although he did not differentiate song from their other vocalisations (Gibb 2000). Azar (2012) compared seasonality of vocalisations of selected native and introduced birds in Zealandia, with results generally consistent with those reported here.

Flocking species like whitehead and silvereye were difficult to count accurately in denser forest vegetation, and highly mobile species may have been counted more than once (e.g., New Zealand falcon, kaka and red-crowned parakeet). Water birds were often mobile too, with ducks, shags and gulls flying around and in/out of Zealandia through count periods. High mobility was less of a problem with forest species like grey warbler and North Island robin, so detections were more likely to reflect seasonal variation in behaviour and conspicuousness. The high proportion of species first heard, especially in forest, stresses the need for observer capability in differentiating the range of vocalisations of bird species in Zealandia. As counts were undertaken by day, one species, the nocturnal little spotted kiwi (*Apteryx owenii*), was not recorded, although it has been acoustically monitored there (Digby *et al.* 2013, 2014).

To conclude, this study of annual and seasonal changes in birds counted at Zealandia provides a baseline against which to measure future change. Future research could usefully focus on the relationship between conspicuousness and abundance in New Zealand species, including comparison of mainland island restoration sites with less protected areas. This study also highlights differences in song output patterns between native and introduced passerines, likely to relate

to phylogenetic differences with their different evolutionary histories. Reasons for these differences also warrant further study.

ACKNOWLEDGEMENTS

I thank Matu Booth, Raewyn Empson, Ron Goudswaard and Bernard Smith of Zealandia eco-sanctuary for providing information that assisted this study, and I am indebted to Lisa Woods for statistical advice. I also thank Joseph Azar for discussions regarding Zealandia counts, Matu Booth, Gill Brackenbury and Lisa Woods for commenting on drafts of this paper, and the reviewers for constructive suggestions.

LITERATURE CITED

- Alexander, H.G. 1938. A chart of the song-periods of British birds. pp. xxxviii-xi (Vol. 1) and pp. xi-xiii (Vol. 2) *In*: Witherby, H.F., Jourdain, F.C.R., Ticehurst, N.F., Tucker, B.W. (eds.) *The handbook of British birds*. London: H.F. & G. Witherby Ltd.
- Azar, J. F. 2012. *Vocal communication within a forest bird community*. Unpubl. PhD thesis, Victoria University of Wellington, Wellington, New Zealand.
- Azar, J.; Bell, B.D. (in press). Acoustic features within a New Zealand forest bird community of native and introduced species. *Emu* (accepted 15 Sept. 2015).
- Bell, B.D. 1972. *Notes for West Coast bird survey group: Relationship of bird counts to weather (and time of day)*. Unpublished report, Ecology Division, Department of Scientific and Industrial Research, Lower Hutt. 3 pp.
- Bell, B.D. 2006. Sustained song from the ground by a male chaffinch (*Fringilla coelebs*) in the Karori Wildlife Sanctuary, Wellington, New Zealand. *Notornis* 53: 2578-260.
- Bell, B. D. 2010. The birds of the south Wellington region. Chapter 27 *In*: Gardner, J.P.A. (ed.). *The Taputeranga Marine Reserve*. Wellington: First Edition Publishers. Revised edition.
- Benjamini, Y.; Hochberg, Y. 1995. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B* 57: 289-300.
- Bibby, C.J.; Burgess, N.D.; Hill, DA. 1992. *Bird census techniques*. London: Academic Press.
- Bibby, C.J.; Jones, M.; Marsden, S. 1998. *Expedition field techniques. Bird surveys*. London: Royal Geographical Society.
- Brockie, R.E. 1992. *A living New Zealand forest*. Auckland: David Bateman.
- Campbell-Hunt, D. 2002. *Developing a sanctuary*. Wellington: Victoria Link Ltd.
- Catchpole, C.K.; Slater, P.J.B. 2008. *Bird song: Biological themes and variations*. 2nd edition. Cambridge: Cambridge University Press.
- Castro, I. 2013. *Stitchbird*. *In*: Miskelly, C.M. (ed.) *New Zealand Birds Online*. Accessed 27 September 2015. www.nzbirdsonline.org.nz
- Cohen, J. 1988. *Statistical power and analysis for the behavioral sciences*. (2nd ed.). Hillsdale, N.J.: Lawrence Erlbaum Associates, Inc.
- Cramér, H. 1999. *Mathematical methods of statistics*. Princeton: Princeton University Press.

- Cramp, S.; Brooks, D.J.; Dunn, E.; Gillmor, R.; Hall-Craggs, J.; Hollom, P.A.D.; Nicholson, E.M.; Ogilvie, M.A.; Roselaar, C.S.; Sellar, P.J.; Simmons, K.E.L.; Voous, K.H.; Wallace, D.I.M.; Wilson, M.G. 1988. *Handbook of the birds of Europe, the Middle East and North Africa. Volume V: tyrant flycatchers to thrushes*. Oxford: Oxford University Press.
- Cramp, S.; Perrins, C.M.; Brooks, D.J.; Dunn, E.; Gillmor, R.; Hall-Craggs, J.; Hollcoat, B.; Hollom, P.A.D.; Nicholson, E.M.; Roselaar, C.S.; Seale, W.T.; Sellar, P.J.; Simmons, K.E.L.; Snow, D.W.; Vincent, D.V.; Voous, K.H.; Wallace, D.I.M.; Wilson, M.G. 1994. *Handbook of the Birds of Europe, the Middle East and North Africa. Volume VIII crows to finches*. Oxford: Oxford University Press.
- Dawson, D.G.; Bull, P.C. 1975. Counting birds in New Zealand forests. *Notornis* 22: 101-109.
- Dawson, D.G.; Dilks, P.J.; Gaze, P.D.; McBurney, J.G.R.; Wilson, P.R. 1978. Seasonal differences in bird counts in forests near Reefton, South Island, New Zealand. *Notornis* 25: 257-278.
- Digby, A.; Towsey, M.; Bell, B.D.; Teal, P.D. 2013. A practical comparison of manual and autonomous methods for acoustic monitoring. *Methods in Ecology and Evolution* 4: 675-683.
- Digby, A.; Bell, B.D.; Teal, P.D. 2014. Acoustic individual discrimination of little spotted kiwi. *Emu* 114: 326-336.
- DOC. 2015. *Mainland islands*. doc.govt.nz/our-work/mainland-islands/ Accessed 25 Sept. 2015. Department of Conservation, New Zealand.
- Empson, R.; Fastier, D. 2013. Translocations of North Island tomtits (*Petroica macrocephala toitoi*) and North Island robins (*P. longipes*) to Zealandia-Karori Sanctuary, an urban sanctuary. What have we learned? *Notornis* 60: 63-69.
- Freeman, A.N.D. 1999. Bird counts in Kennedy's Bush Scenic Reserve, Port Hills, Christchurch. *Notornis* 46: 388-404.
- Gibb, J. A. 1996. First seen or first heard? A useful distinction when counting forest birds. *Notornis* 43: 7-13.
- Gibb, J.A. 2000. Activity of birds in the Western Hutt Hills, New Zealand. *Notornis* 47: 13-35.
- Gibbons, D.W.; Hill, D.A.; Sutherland, W.J. 1996. Birds. Pp. 227-59 In: Sutherland, W.J. (ed.). *Ecological Census Techniques*. Cambridge: Cambridge University Press.
- Gill, B.J.; Bell, B.D.; Chambers, G.K.; Medway, D.G.; Palma, R.L.; Scofield, R.P.; Tennyson, A.J.D.; Worthy, T.H. 2010. *Checklist of the birds of New Zealand, Norfolk and Macquarie Islands, and the Ross Dependency, Antarctica*. 4th ed. Wellington, Te Papa Press, 501 pp.
- Handford, P.A. 2002. *Native forest monitoring: a guide for forest owners and managers*. Paekakariki, New Zealand: FRONZ.
- Hartley, L.J. 2012. Five-minute bird counts in New Zealand. *New Zealand Journal of Ecology* 36: 268-278.
- Jenkins, P.F.; Baker, A.J. 1984. Mechanisms of song differentiation in introduced populations of chaffinches *Fringilla coelebs* in New Zealand. *Ibis* 126: 510-524.
- Krause, B. 1987. Bioacoustics, habitat ambience in ecological balance. *Whole Earth Review* 57: 14-18.
- Krause, B.L. 1993. The niche hypothesis: a hidden symphony of animal sounds, the origins of musical expression and the health of habitats. *Explorers Journal* 71: 156-160.
- Krebs, C.J. 1999. *Ecological methodology*. 2nd edition. USA, Benjamin Cummings, Addison-Wesley Educational Publishers, Inc.
- McDavitt, B. 2011. Story behind polar outbreak of August 2011. <http://blog.metservice.com/2011/08/story-behind-polar-outbreak-of-august-2011>. Accessed 16 November 2014.
- Miskelley, C.; Empson, R.; Wright, K. 2005. Forest birds recolonising Wellington. *Notornis* 52: 21-26.
- Morgan, D.K.J.; Waas, J.R.; Innes, J.; Arnold, G. 2012. Native bird abundance after Australian magpie (*Gymnorhina tibicen*) removal from localised areas of high resource availability. *New Zealand Journal of Ecology* 36: 333-339.
- O'Donnell, C.F.J. 1996. Monitoring mohua (yellowhead) populations in the South Island, New Zealand, 1983-93. *New Zealand Journal of Zoology* 23: 221-228.
- Parker, K.A. 2013. North Island saddleback. In: Miskelley, C.M. (ed.) *New Zealand Birds Online*. Accessed 27 September 2015. www.nzbirdsonline.org.nz
- Powlesland, R.G. 2013. New Zealand fantail. In: Miskelley, C.M. (ed.) *New Zealand Birds Online*. Accessed 27 September 2015. www.nzbirdsonline.org.nz
- Reese, P. 2012. Wellington NZ bird banders: The group's banding results for 2011/12. Accessed 22 April 2012. wgtmnbanders.blogspot.com/
- Saunders, A.; Norton, D.A. 2001. Ecological restoration at Mainland Islands in New Zealand. *Biological Conservation* 99: 109-119.
- Smith, A.N.H.; Westbrooke, I.M. 2004. Changes in conspicuousness at Pureora Forest. *Notornis* 51: 21-25.
- Spurr, E.B. 2005. Monitoring bird populations in New Zealand: a workshop to assess the feasibility of a national bird population monitoring scheme. *Landcare Research Science Series* 28, Lincoln, New Zealand. 29 p.
- Sullivan, J.J. 2012. Recording birds in real time: a convenient method for frequent bird recording. *New Zealand Journal of Ecology* 36: 416-424.
- Sutherland, W.J. 2000. *The conservation management handbook: Research, management and policy*. Oxford: Blackwell Science.
- Taylor, S.S.; Jamieson, I.G.; Armstrong, D.P. 2005. Successful island reintroductions of New Zealand robins and saddlebacks with small numbers of founders. *Animal Conservation* 8: 415-420.
- Tomkins, D. 2012. Introduction to the special issue on advances in tools for bird population monitoring in New Zealand. *New Zealand Journal of Ecology* 36: 1.
- Verner, J. 1985. Assessment of counting techniques. Pp. 247-301 In: Johnston, R.F. (ed.). *Current Ornithology*, Vol. 2. New York: Plenum Press.
- Warne, K. 2002. Hotspot: New Zealand. *National Geographic* 202: 74-101.
- Witherby, H.F.; Jourdain, F.C.R.; Ticehurst, N.F.; Tucker, B.W. 1938. *The handbook of British birds. Vol. I. Crows to flycatchers*. London: H.F. & G. Witherby Ltd.
- Zealandia. 2012. *Bird-watching list for Zealandia (Karori Sanctuary)*, Wellington, New Zealand. *Native, endemic and introduced birds*. Karori Sanctuary Trust, Wellington.
- Zealandia. 2014. *Zealandia. The Karori Sanctuary experience. Te Mara a Tane. A souvenir guide*. Karori Sanctuary Trust, Wellington.
- Zealandia. 2014. *Zealandia. The Karori Sanctuary experience, Te Mara a Tane*. visitzealandia.com. Accessed 29 December 2014.

Appendix 1. Initial detection method (% seen and % heard) and the seasonal and annual mean number of birds per count detected in Zealandia over 2011-2015. The annual mean is for the seasonal year (Sept.-Aug.).

Species	Initial detection (%)		Seasonal mean no. birds per count (\pm se)				Annual mean no. birds per count (\pm se)			
	Seen	Heard	Winter	Spring	Summer	Autumn	Year 1	Year 2	Year 3	Year 4
California quail	92.6	7.4	1.7 \pm 0.6	1.6 \pm 0.5	3.8 \pm 0.8	1.1 \pm 0.5	1.5 \pm 0.5	2.0 \pm 0.7	1.9 \pm 0.6	3.0 \pm 0.8
Paradise shelduck	93.8	6.2	1.6 \pm 0.4	3.6 \pm 1.1	6.4 \pm 0.7	3.3 \pm 0.5	4.4 \pm 0.7	2.9 \pm 0.4	2.8 \pm 0.7	4.9 \pm 1.1
Brown teal	97.5	2.5	4.0 \pm 0.6	2.0 \pm 0.3	2.2 \pm 0.5	3.0 \pm 0.4	2.8 \pm 0.4	2.1 \pm 0.5	3.5 \pm 0.5	2.7 \pm 0.6
Mallard	98.8	1.2	26.3 \pm 3.0	21.5 \pm 2.2	29.9 \pm 3.2	36.7 \pm 4.8	20.8 \pm 2.4	26.5 \pm 3.9	35.2 \pm 4.5	32.6 \pm 2.6
NZ scaup	98.9	1.1	5.8 \pm 0.6	8.8 \pm 1.0	11.2 \pm 1.7	8.4 \pm 1.1	5.0 \pm 0.3	11.8 \pm 1.2	7.0 \pm 0.8	11.7 \pm 1.6
New Zealand dabchick	100.0	0.0	0.1 \pm 0.1	0.1 \pm 0.1	0.2 \pm 0.1	0.2 \pm 0.1	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.5 \pm 0.1
Little shag	99.5	0.5	3.0 \pm 1.4	4.4 \pm 0.7	3.7 \pm 0.7	1.3 \pm 0.4	4.4 \pm 1.3	1.9 \pm 0.5	3.2 \pm 0.8	2.6 \pm 0.4
Black shag	100.0	0.0	0.8 \pm 0.2	2.2 \pm 0.3	1.7 \pm 0.6	1.3 \pm 0.4	2.0 \pm 0.6	2.2 \pm 0.4	1.3 \pm 0.3	0.4 \pm 0.2
Pied shag	100.0*	0.0	22.1 \pm 2.7	23.7 \pm 1.8	20.0 \pm 2.4	24.1 \pm 2.5	13.3 \pm 1.1	19.6 \pm 1.3	25.3 \pm 1.6	31.9 \pm 2.5
Little black shag	100.0	0.0	1.4 \pm 1.0	1.6 \pm 0.6	3.8 \pm 0.6	1.7 \pm 0.7	3.6 \pm 0.9	0.8 \pm 0.4	1.7 \pm 0.6	2.3 \pm 0.6
Swamp harrier	100.0	0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0	0.2 \pm 0.1	0.2 \pm 0.1	0.1 \pm 0.1	0.0 \pm 0.0	0.0 \pm 0.0
New Zealand falcon	16.4	83.6	0.5 \pm 0.2	1.0 \pm 0.3	0.8 \pm 0.2	0.7 \pm 0.2	0.5 \pm 0.3	0.7 \pm 0.2	0.8 \pm 0.2	1.1 \pm 0.2
Pukeko	100.0	0.0	0.1 \pm 0.1	0.0 \pm 0.0	0.0 \pm 0.0	0.1 \pm 0.1	0.2 \pm 0.1	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0
South Island takahe	99.1	0.9	1.8 \pm 0.1	1.3 \pm 0.2	1.3 \pm 0.1	1.8 \pm 0.1	1.6 \pm 0.2	1.5 \pm 0.1	1.7 \pm 0.2	1.4 \pm 0.2
Black-backed gull	89.8	10.2	0.5 \pm 0.2	1.4 \pm 0.3	1.8 \pm 0.4	3.6 \pm 1.1	1.8 \pm 0.6	3.2 \pm 1.2	1.3 \pm 0.3	1.2 \pm 0.2
New Zealand pigeon	77.8	22.2	2.7 \pm 0.5	3.4 \pm 0.7	4.2 \pm 0.9	2.1 \pm 0.5	1.2 \pm 0.3	3.4 \pm 0.7	3.9 \pm 0.7	4.2 \pm 0.8
Kaka	24.1	75.9	27.9 \pm 2.2	32.0 \pm 1.9	30.3 \pm 1.5	24.1 \pm 2.4	23.6 \pm 2.4	29.6 \pm 2.5	30.9 \pm 1.5	30.7 \pm 1.6
Eastern rosella	7.5	92.6	1.1 \pm 0.3	4.9 \pm 0.4	2.6 \pm 0.3	2.2 \pm 0.3	2.6 \pm 0.4	3.8 \pm 0.4	2.7 \pm 0.5	1.8 \pm 0.4
Red-crowned parakeet	26.8	73.2	11.1 \pm 1.5	6.1 \pm 0.8	7.5 \pm 0.9	10.2 \pm 1.1	5.8 \pm 0.8	6.3 \pm 0.8	10.6 \pm 1.2	12.2 \pm 1.1
Shining cuckoo	0.8	99.3	0.0 \pm 0.0	5.1 \pm 0.9	2.5 \pm 0.7	0.0 \pm 0.0	1.8 \pm 0.8	2.7 \pm 1.0	1.6 \pm 0.7	1.4 \pm 0.6
Long-tailed cuckoo	0.0	100.0	0.0 \pm 0.0	0.0 \pm 0.0	0.1 \pm 0.1	0.0 \pm 0.0	0.1 \pm 0.1	0.0 \pm 0.0	0.0 \pm 0.0	0.0 \pm 0.0
Morepork	100.0	0.0	0.1 \pm 0.1	0.2 \pm 0.1	0.0 \pm 0.0	0.1 \pm 0.1	0.1 \pm 0.1	0.1 \pm 0.1	0.0 \pm 0.0	0.1 \pm 0.1
New Zealand kingfisher	15.7	84.3	0.1 \pm 0.1	2.0 \pm 0.3	1.8 \pm 0.3	0.6 \pm 0.2	1.1 \pm 0.4	0.9 \pm 0.3	1.3 \pm 0.3	1.3 \pm 0.4
North Island saddleback	13.2	86.8	31.6 \pm 1.6	33.7 \pm 1.6	35.1 \pm 1.3	40.6 \pm 1.8	34.0 \pm 1.6	33.3 \pm 2.0	37.0 \pm 1.5	36.5 \pm 2.0
Stitchbird	33.3	66.7	19.7 \pm 1.5	23.4 \pm 1.6	25.9 \pm 1.1	24.2 \pm 1.7	23.2 \pm 1.5	21.5 \pm 2.2	22.2 \pm 1.2	26.4 \pm 1.3
Grey warbler	4.7	95.3	23.4 \pm 3.3	45.0 \pm 2.0	21.7 \pm 1.8	16.5 \pm 2.0	26.5 \pm 3.2	26.9 \pm 4.3	27.9 \pm 3.5	24.1 \pm 2.9

Appendix 1. Continued.

Bellbird	21.3	78.7	9.7 ± 1.9	11.8 ± 1.0	11.6 ± 1.0	11.5 ± 1.6	15.5 ± 1.6	11.3 ± 1.7	9.3 ± 0.8	8.1 ± 0.8
Tui	22.3	77.7	58.1 ± 7.6	49.2 ± 3.2	62.9 ± 3.2	71.7 ± 5.4	60.4 ± 5.6	58.9 ± 5.4	61.7 ± 4.5	61.4 ± 6.4
Whitehead	16.8	83.2	95.2 ± 5.1	103.2 ± 4.7	93.3 ± 4.2	99.6 ± 4.5	85.7 ± 3.6	97.3 ± 4.3	98.9 ± 4.4	110.1 ± 4.5
New Zealand fantail	12.5	87.5	11.1 ± 1.6	7.7 ± 1.3	12.1 ± 2.1	14.1 ± 2.0	4.2 ± 0.7	9.3 ± 1.4	13.9 ± 1.2	18.1 ± 1.9
North Island robin	29.7	70.4	25.1 ± 2.0	25.4 ± 2.2	54.5 ± 3.9	51.4 ± 2.8	39.2 ± 4.4	42.3 ± 4.6	37.6 ± 3.9	39.4 ± 4.8
Silvereye	10.6	89.4	32.7 ± 6.3	12.5 ± 1.5	58.5 ± 16.3	142.3 ± 11.2	65.5 ± 14.8	90.4 ± 20.7	47.6 ± 12.6	50.1 ± 15.0
Welcome swallow	92.6	7.4	0.3 ± 0.2	1.3 ± 0.2	2.4 ± 0.7	0.6 ± 0.3	0.4 ± 0.2	2.8 ± 0.9	1.1 ± 0.3	0.8 ± 0.4
Eurasian blackbird	37.6	62.4	31.1 ± 2.3	39.9 ± 2.3	52.4 ± 4.3	51.8 ± 3.1	41.8 ± 3.6	50.4 ± 4.2	46.6 ± 3.8	38.3 ± 3.3
Song thrush	12.4	87.6	1.6 ± 0.5	2.2 ± 0.2	1.2 ± 0.3	1.0 ± 0.3	1.5 ± 0.3	1.0 ± 0.3	1.9 ± 0.4	1.3 ± 0.4
Common starling	70.9	29.1	1.4 ± 0.7	1.7 ± 0.7	6.3 ± 0.8	6.2 ± 2.8	3.2 ± 1.0	2.4 ± 0.9	7.2 ± 2.6	2.7 ± 0.7
House sparrow	66.2	33.8	4.7 ± 0.9	3.5 ± 0.7	7.0 ± 1.2	6.4 ± 1.2	1.0 ± 0.4	5.3 ± 1.1	6.9 ± 0.7	8.9 ± 1.0
Dunnoek	27.5	72.5	6.9 ± 0.8	10.1 ± 0.7	5.4 ± 0.7	4.2 ± 0.7	6.9 ± 0.9	7.7 ± 0.8	7.1 ± 1.0	4.8 ± 0.6
Chaffinch	21.5	78.5	10.9 ± 1.5	23.8 ± 2.1	18.9 ± 1.9	9.9 ± 1.3	16.4 ± 2.2	18.3 ± 2.0	14.2 ± 1.9	14.8 ± 2.5
European greenfinch	22.7	77.3	2.2 ± 0.7	5.5 ± 0.9	4.5 ± 0.7	2.6 ± 0.6	4.5 ± 0.6	6.6 ± 1.0	1.7 ± 0.4	2.4 ± 0.7
European goldfinch	18.5	81.6	0.4 ± 0.2	1.9 ± 0.7	2.4 ± 0.4	1.0 ± 0.3	0.8 ± 0.3	2.7 ± 0.7	0.9 ± 0.3	1.8 ± 0.4
Common redpoll	0.0	100.0	0.1 ± 0.1	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1
Yellowhammer	50.0	50.0	0.3 ± 0.2	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2
Total for all species	32.6	67.5	479.0 ± 14.3	528.6 ± 12.3	605.0 ± 21.5	673.9 ± 24.2	513.6 ± 18.9	610.5 ± 33.1	581.1 ± 22.4	598.1 ± 25.3

* Some pied shag colony birds heard before seen, but not identified, so uncertain how many