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New Zealand Garden Bird Survey – analysis of the first four years

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Abstract: The New Zealand Garden Bird Survey started in 2007 primarily to monitor long-term trends in common garden bird populations. The method was based on the Big Garden Birdwatch in the UK. Volunteers spent one hour in midwinter each year recording for each bird species the largest number of individuals detected at any one time in their gardens, as an index of abundance. A large number of species was recorded, the two most numerous being house sparrow (*Passer domesticus*) and silvereye (*Zosterops lateralis*). There was regional variation in species occurrence and abundance; more species and more individuals of most species in rural than in urban gardens; more individuals of some species and fewer of others in gardens where supplementary food was provided; and changes in the abundance of some species over the 4 years. Potential problems with the methodology and interpretation of the data are discussed. As a consequence of convenience sampling the results apply only to the gardens of participants, not necessarily New Zealand as a whole. The survey has the potential to alert authorities to changes in garden bird population trends, and to provide circumstantial evidence of the success or otherwise of management actions such as restoration planting.

Keywords: abundance; indices; occurrence; population monitoring; population trends; supplementary feeding

Introduction

Garden bird surveys are undertaken at least annually in several countries for monitoring bird population trends (Cannon 1999; LePage & Francis 2002; Veerman 2003; Cannon et al. 2005; Chamberlain et al. 2005; Bonter & Hochachka 2009). Some surveys monitor all birds visiting gardens, e.g. the Garden Birdwatch (www.bto.org/gbw) and Big Garden Birdwatch (www.rspb.org.uk/birdwatch) in the UK, Canberra Garden Bird Survey (http://garden.canberrabirds.org.au) and Backyard Birds Survey (www.birdsinbackyards.net) in Australia, and Great Backyard Bird Count in North America (www.birdsource.org/gbbc). Others are restricted just to gardens where supplementary food and/or water are provided, e.g. the Garden Bird Feeding Survey (www.bto.org/survey/gbfs.htm) in the UK and Project FeederWatch (www.birds.cornell.edu/pfw) in North America. Some of the surveys are restricted to winter, but others run throughout the year. All use volunteers to record either the presence of bird species or the highest number of each bird species detected at any one time during a set observation period (ranging from 15 min to 1 week). The largest survey is the Big Garden Birdwatch in the UK, which in recent years has been undertaken in about 280 000 gardens (1% of the total households) annually.

This paper describes the establishment of an annual winter garden bird survey in New Zealand. New Zealand has a number of native bird species that are either resident in domestic gardens year round or visit domestic gardens in winter. Some of these are of conservation concern; e.g. kaka, North Island saddleback, and stitchbird (see Appendix 1a and 1b for scientific names of bird species, after Gill et al. 2010). The primary objective of the survey is to monitor long-term trends in common garden bird populations. Other objectives are to provide data to assist local authorities with the planning and management of their biodiversity responsibilities, to provide an opportunity for the general public to become involved in science in their own gardens ('citizen science'), and to educate and raise awareness of participants about biodiversity, birds, conservation, and the environment, and at the same time to have fun. The survey has been running for only 4 years so it is too soon to report on long-term trends, but some preliminary results are presented to illustrate the survey's potential and to investigate the effects on counts within species of four factors individually (region of the country in which the counts were made, urban compared with rural areas, provision of supplementary food, and year).

Methods

The New Zealand Garden Bird Survey was based on the Big Garden Birdwatch in the UK (www.rspb.org.uk/birdwatch). It started nationwide in 2007, after a small trial in 2006.

Volunteers were asked to count, for each bird species they detected, the largest number of individuals seen and/or heard at any one time in a one-hour period between specified dates in late June and/or early July (New Zealand winter) (Appendix 2) in their home gardens, public parks, or school grounds. Returns from public parks, school grounds, and other unsolicited sites comprised about 5% of the total and have been excluded from this paper because the results differ from those of home gardens. Additional information recorded included the geopolitical region of the country in which the survey was done (selected from the 16 territorial authorities listed in Appendix 3), whether the garden was urban or rural (in the opinion of the participants), whether or not supplementary food was provided for birds, and if it was, what types of food were provided (namely, bread, fat, fruit, seeds, sugar-water, and/or other), and whether the survey area included the area where birds were fed. The main difference between the New Zealand and UK surveys is that the New Zealand survey runs for 9 days (two weekends plus the weekdays between) rather than 2 days (one weekend) as in the UK survey.

A Garden Bird Survey website was established (www.landcareresearch.co.nz/research/biocons/gardenbird), which included full instructions, a bird identification guide, a printable survey form, and an online data-entry form. Previous participants were emailed reminders of the survey, and the event was publicised by the Royal Forest and Bird Protection Society, Ornithological Society of New Zealand, local councils, newspapers, radio, and television. Hardcopy survey forms were distributed through various community groups. The survey form was also published by some regional newspapers (i.e. *The Press* in 2007, 2008, and 2010; *The Dominion Post* in 2008 and 2009; *Otago Daily Times* in 2008 and 2010; *Ashburton Guardian* in 2007 and 2008; *Dannevirke News* in 2007; and *Westport News* in 2008) and by *Forest & Bird* magazine in 2009 and 2010.

The number of survey returns that came from each region of the country was not in proportion to the number of households in each region, based on 2006 figures, the latest available from Statistics New Zealand (www.stats.govt.nz) (Appendix 3). Furthermore, the percentage of survey returns that came from each region varied from year to year, partially reflecting whether or not regional newspapers published the survey form. For example, the Auckland region had 30% of New Zealand households in 2006 but provided only 12%, 4%, 15%, and 11% of the bird survey returns in the four years, 2007–2010 (Appendix 3). The Auckland newspaper, *The New Zealand Herald*, New Zealand's largest, did not publish the survey form in any of the years. On the other hand, the Wellington region had 11% of households and provided 5%, 36%, 31%, and 13% of the survey returns. As noted above, the Wellington newspaper, *The Dominion Post*, published the survey form in 2008 and 2009, the two years with high returns. The number of survey returns from each region influenced the national percentage of gardens in which species were recorded and the national average number of each species counted per garden. To overcome this problem, the regional percentages of gardens in which species were recorded and the regional average numbers of each species counted per garden were multiplied by the proportion of the total number of households in New Zealand in each region, and these values were summed to provide more representative national percentages and averages. The weighting is approximate only because some households (e.g. apartments) do not have individual gardens, and some regions have a higher proportion of households without gardens than others.

The number of survey returns from some regions was very small (Appendix 3). Consequently, Gisborne was combined with Hawke's Bay, Bay of Plenty with Waikato, Taranaki with Manawatu-Wanganui, and Nelson City with Tasman and Westland, reducing the number of regions to 11. Even then some sample sizes were still small (Appendix 3). Some regions with small sample sizes were kept separate (i.e. Northland, Marlborough, and Southland) to retain a geographic spread. As a consequence of small sample sizes some regional results may be unreliable.

Some survey returns were entered directly online by participants and others (hardcopy returns) were entered into the database by volunteers. The online and hardcopy forms both had a fixed list of 22 of the more likely species names and the online form also had a drop-down list of the less likely names, ensuring consistency of naming and spelling. However, data-entry errors still occurred, for example, when a species recorded on the hardcopy form was not entered, the wrong species (e.g. the one next to that intended) was entered, or the wrong number of birds observed was entered. I have checked and verified the data as much as possible, for example by screening species names, species occurrence by region, and maximum count values. When potential observer errors were identified, I attempted to contact participants to discuss and, if necessary, edit their observations. Unfortunately, not all participants could be contacted and probably not all errors were detected. However, the errors remaining are likely to affect less than 0.1% of the data. Overall, most participants appeared to have a good knowledge of birds, and some wrote (sometimes lengthy) descriptions of all birds that usually visited their gardens but did not visit during the survey.

Analysis of the data is only preliminary. The relationship between the average maximum number counted per garden (index of abundance) and percentage of gardens in which species occurred was determined using regression and Pearson's correlation coefficient (r). Mood's median test was used to determine whether the median counts of the samples being compared within each of the factors being investigated (region, urban compared with rural, the provision or not of supplementary food, and year) were identical (Siegel & Castellan 1988). This involved assigning the counts in each sample to two groups, above and below or equal to the median of the combined samples, and using Pearson's chi-square test (χ^2) on the raw data to determine whether the proportion of counts in the two groups differed between samples. The results are indicative only because the test assumes the regional proportions of participants were the same each year and reflect the regional proportions of households (i.e. the data could not be weighted using this method of analysis). The test also assumes no significant interaction between factors. A generalised linear models analysis is planned when more years' data have been collected. Regional variation in the proportion of participants providing supplementary food for birds was analysed by comparing observed numbers with expected numbers obtained from the regional proportions of gardens surveyed, using a chi-squared goodness-of-fit test, and if significant differences were found Bonferroni-adjusted confidence intervals ($P < 0.05$) were used to determine which regions had observed values significantly different from their expected (Byers et al. 1984).

Results

National occurrence and abundance

A total of 106 species was recorded over the 4 years (83–91 each year). However, 72 of these were recorded in less than 1% of gardens, and some in only one garden. Thirty-four species were recorded in 1% or more of gardens in one or more of the years (Appendix 1a), and 21 species in 10% or more of gardens (Fig. 1). The average number of species per garden was 7.7 (7.6–7.9 each year) and the range 0–24.

Eurasian blackbird was recorded in about 90% of gardens nationwide, more than any other species (Fig. 1). House sparrow was recorded in 88%, silvereye in 81%, common starling in 60%, and all other species in less than 50% of the gardens surveyed. Weighting the regional percentages by the proportion of households in each region increased the national percentage of gardens in which some species were recorded and decreased the national percentage for other species. For example, common myna was present in 16% of gardens nationwide when the percentage was calculated from all survey returns irrespective of how many came from each region, but this figure increased to 35% (and its ranking from 16^{th} to 9^{th}) when the percentage was calculated from weighted regional percentages. The increase in occurrence (and ranking) occurred because most households (74%) occurred in North Island regions, and so more weight was put on the percentage of gardens with myna in North Island regions than in South Island regions, which had no myna (see below). Likewise, tui occurrence nationwide increased from 42% to 52% of gardens (and its ranking from 7^{th} to 5^{th}) when regional percentages were weighted by the regional proportion of households, because although most households (30%) occurred in Auckland a disproportionate number of survey returns came from Canterbury, where tui occurrence was very low (see below). On the other hand, bellbird occurrence decreased from 26% to 20% and dunnock occurrence decreased from 24% to 16% of gardens nationwide because both bellbird and dunnock occurrence were very low in Auckland, where most households occurred.

The species with the highest count nationally (average maximum number per garden over the 4 years) was the house sparrow, followed by silvereye, starling, and blackbird (Fig. 1). As with occurrence, weighting regional average counts by the proportion of households in each region increased the national average count for some species (e.g. myna and tui) and decreased the national average count for other species (e.g. bellbird and dunnock). There was a strong positive correlation between weighted average counts (indices of abundance) and percentage occurrence of the 21 species recorded in 10% or more of gardens nationally ($r = 0.91$, d.f. = 19, $P < 0.001$, $r^2 = 0.82$).

Regional occurrence and abundance

The percentage of gardens in which species occurred varied regionally, and between the North Island and South Island (Fig. 2). The most extreme variation was for myna, which occurred only in North Island regions. Tui, bellbird, and dunnock also had large variations in regional occurrence. Tui, for example, occurred in only 2% of gardens in Canterbury compared with 52% of gardens nationally. Species that occurred in a higher percentage of gardens in the North Island included

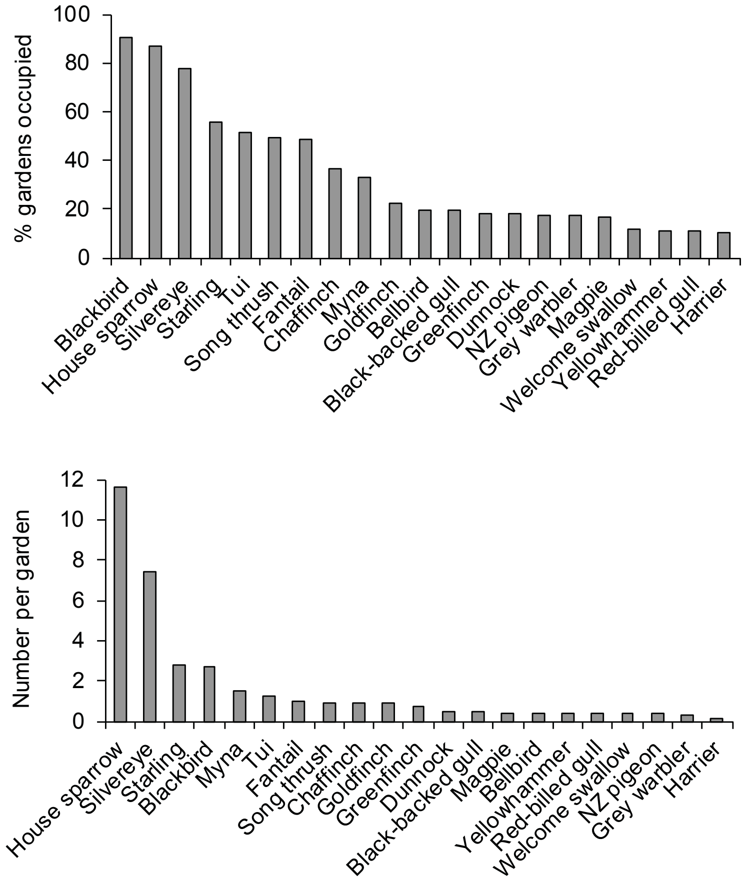
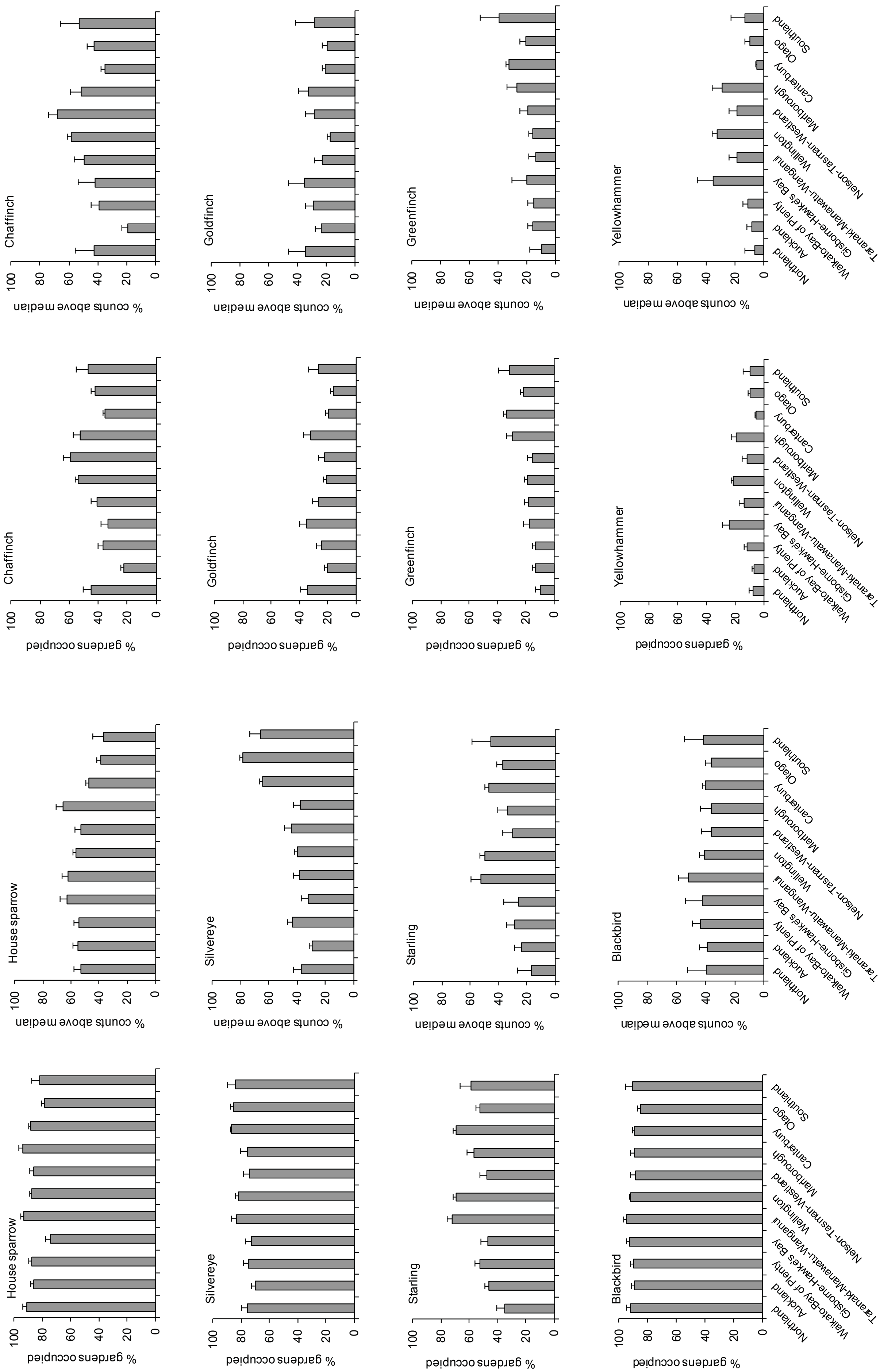


Figure 1. Percentage of gardens occupied (above) and average number of birds per garden (below) for species that were recorded in 10% or more of gardens, average 2007–2010 (from the sum of regional values weighted by the proportion of households in each region).


House sparrow
Silvereye
Starling
Blackbird
Chaffinch
Goldfinch
Greenfinch
Yellowhammer
% gardens occupied
% counts above median
Northland
Auckland
Waikato-Bay of Plenty
Gisborne-Hawkes Bay
Taranaki-Manawatu-Wanganui
Wellington
Nelson-Tasman-Westland
Marlborough
Canterbury
Otago
Southland

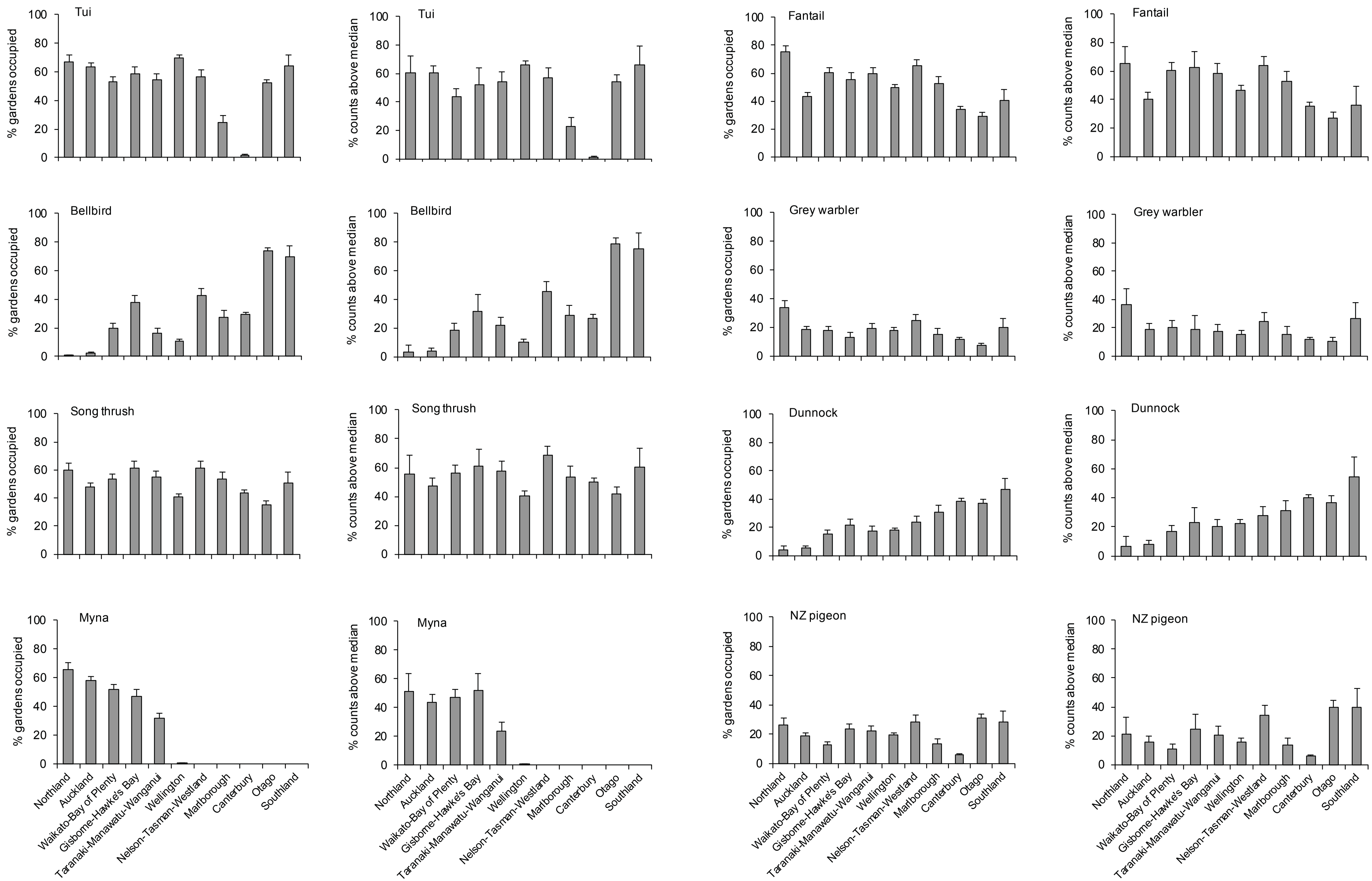


Figure 2. Percentage of gardens occupied (left) and percentage of counts above the median (right) (± 95% binomial confidence limits) recorded in different regions of New Zealand, average 2007–2010 (see Appendix 3 for number of gardens surveyed in each region).

house sparrow, blackbird, song thrush, European goldfinch, myna, tui, New Zealand fantail, grey warbler, and New Zealand pigeon (Fig. 2). Species that occurred in a higher percentage of gardens in the South Island included silvereye, starling, chaffinch, European greenfinch, dunnock, and bellbird.

Median counts of the top 21 species varied between regions (χ^2 values all $P < 0.001$, d.f. = 10) and as with occurrence showed two main patterns, higher in the north or higher in the south of the country (Fig. 2). For example, house sparrow counts were higher in Northland and Auckland combined than in Canterbury, Otago, and Southland combined (χ^2 for all gardens = 43.7, d.f. = 1, $P < 0.001$; χ^2 for gardens where birds were not fed = 13.4, d.f. = 1, $P < 0.001$). On the other hand, silvereye counts were higher in the three southern South Island regions than in the two northern North Island regions (χ^2 for all gardens = 626.0, d.f. = 1, $P < 0.001$; χ^2 for gardens where birds were not fed = 15.9, d.f. = 1, $P < 0.001$). Counts of silvereye were higher than those of house sparrow in Canterbury, Otago, and Southland but counts of house sparrow were higher than those of silvereye in all other regions. In addition to house sparrow, other species with higher counts in the North Island were myna, blackbird, song thrush, tui, fantail, and grey warbler. In addition to silvereye, other species with higher counts in the South Island were starling, chaffinch, greenfinch, bellbird, goldfinch, dunnock, and New Zealand pigeon.

There was a positive correlation between regional average counts (indices of abundance) and regional percentage occurrence in gardens within species, with r values ranging from 0.72 (d.f. = 9, $P = 0.013$) to 1 (d.f. = 9, $P < 0.001$), most above 0.846 (the $P = 0.001$ value). In the North Island, there was an inverse relationship between myna and starling counts ($r = 0.89$, d.f. = 4, $P = 0.018$, $r^2 = 0.79$) and between myna and starling occurrence ($r = 0.91$, d.f. = 4, $P = 0.011$, $r^2 = 0.83$). A more detailed analysis of the relationship between abundance and occurrence will be presented in another paper.

Urban compared with rural gardens

Most survey returns (76%) came from urban rather than rural gardens, but rural gardens had more species per garden than urban gardens (9.9 compared with 7.0). Some participants in rural areas included surrounding farmland, ponds, rivers, and adjacent patches of native forest as part of their garden, and recorded open-country species such as paradise shelduck, pukeko, spur-winged plover, white-faced heron, and wild turkey, and forest species such as North Island robin, rifleman, tomtit, and whitehead as being in their garden. Some participants in coastal areas included the sea as part of their garden, and recorded species such as Australasian gannet, fluttering shearwater, pied shag, reef heron, and white-fronted tern. However, these species were recorded in only one or a few gardens.

Some species more usually associated with native forest were also recorded in urban gardens. For example, a stitchbird (with coloured leg-bands) was recorded in an urban garden in Waitakere City (Auckland), having moved at least 2 km from the Waitakere Ranges. Kaka and North Island saddleback were reported from urban gardens in Wellington, having flown up to 4 km from Karori Wildlife Sanctuary. A New Zealand falcon chasing a tui was reported from an urban garden in Silverstream (Wellington). Red-crowned parakeets were reported from urban gardens in Torbay and Glenfield (Auckland), about 15 km and 25 km respectively from the nearest known breeding population on Tiritiri Matangi Island.

Median counts of most species were higher in rural gardens than in urban gardens (χ^2 values all $P < 0.001$, d.f. = 1) (Fig. 3). However, house sparrow, silvereye, southern black-backed gull, greenfinch, and red-billed gull counts were higher in urban gardens (χ^2 values all $P < 0.001$, d.f. = 1). Rock pigeon and spotted dove counts (not shown in Fig. 3) were also higher in urban gardens. Starling counts were similar in the two types of garden ($\chi^2 = 0.45$, d.f. = 1, $P = 0.503$). The same patterns occurred in most regions.

Median counts of house sparrow, silvereye, and greenfinch were not significantly different in urban compared with rural areas in gardens where birds were not fed (χ^2 values all $P > 0.05$, d.f. = 1). However, counts of both gull species were still significantly higher in urban gardens (both $P < 0.001$, d.f. = 1).

Effects of providing supplementary food

Most survey returns (66%) came from gardens in which supplementary food was provided for birds. An additional 6% of survey participants provided food for birds but not in the area or at the time they did their survey (i.e. a total of 72% of participants fed birds). Of the participants who provided food, 71% provided bread, 52% seeds, 50% fat, 45% fruit, 25% sugar-water, and 10% a large range of other foods such as meal scraps. The percentage of participants providing food (of any type) varied regionally, apparently by latitude, from about 50% in Northland to 86% in Southland ($\chi^2 = 131.7$, d.f. = 10, $P < 0.001$ on raw data). Significantly fewer participants

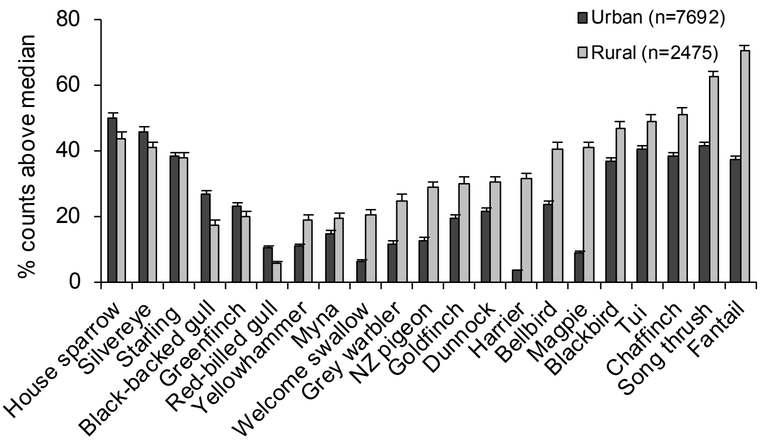


Figure 3. Percentage of counts above the median (± 95% binomial confidence limits) recorded in urban and rural gardens, average 2007–2010 (n = number of gardens surveyed). Differences between urban and rural significant ($P < 0.05$) for all species except starling.

than expected provided food in Northland, Auckland, Bay of Plenty, and Waikato, and significantly more than expected provided food in Canterbury, Otago, and Southland (all $P < 0.05$ from Bonferroni-adjusted confidence intervals). The latitudinal variation was significant for all food types, but was greatest for sugar-water. More participants in Otago and Southland (74%) than elsewhere in the country (average 22%) who provided food for birds provided sugar-water ($\chi^2 = 1321.7$, d.f. = 1, $P < 0.001$). Supplementary food was also provided in a higher percentage of surveyed urban gardens than rural gardens (70% compared with 54%).

The number of species per garden was similar in gardens where supplementary food (of any type) was provided for birds and in gardens where it was not. However, the median counts of some species were higher and of others lower where supplementary food was provided (Fig. 4). For example, the number of counts above the median was 2.1 times higher for house sparrow and 2.4 times higher for silvereye in gardens where birds were fed than in gardens where they were not fed (χ^2 values both $P < 0.001$, d.f. = 1). The number of starling, chaffinch, bellbird, dunnock, greenfinch, and yellowhammer counts above the median were also higher in gardens where birds were fed (χ^2 values all $P < 0.001$, d.f. = 1). These species were all attracted to supplementary food of one type or another. Other species attracted to supplementary food (not shown in Fig. 4) included kaka and stitchbird. On the other hand, the number of counts of red-billed gull, welcome swallow, swamp harrier, New Zealand pigeon, Australian magpie, myna, grey warbler, goldfinch, black-backed gull, tui, song thrush, and fantail above the median were lower in gardens where birds were fed than where they were not fed (χ^2 values all $P < 0.001$ except song thrush $P = 0.011$, d.f. = 1). Blackbird counts were similar in both types of garden ($\chi^2 = 2.6$, $P = 0.106$, d.f. = 1). The same patterns occurred in most regions and in urban and rural gardens.

The number of counts of silvereye, tui, and bellbird above the median were highest in gardens where sugar-water (with and without other supplementary food) was provided (Fig. 5). For silvereye they were 3.7 times higher, tui 1.1 times higher, and bellbird 2.3 times higher than in gardens where there was no supplementary food (χ^2 values all $P < 0.001$, d.f. = 1). The maximum numbers of these species counted at (separate) sugar-water feeders were 400 silvereyes, 58 tui, and 45 bellbirds. Some participants reported that silvereyes consumed large quantities of sugar-water (up to 10 L daily). A more detailed analysis of supplementary feeding will be presented in another paper.

Changes between years

Median counts of all the top 21 species varied between years (χ^2 values all $P \leq 0.001$) except grey warbler ($P = 0.294$, d.f. = 3) (Fig. 6). House sparrow counts increased by 19% nationally over the 4 years ($\chi^2 = 51.9$, d.f. = 3, $P < 0.001$, on raw data). The increase occurred in most regions of the country. Silvereye

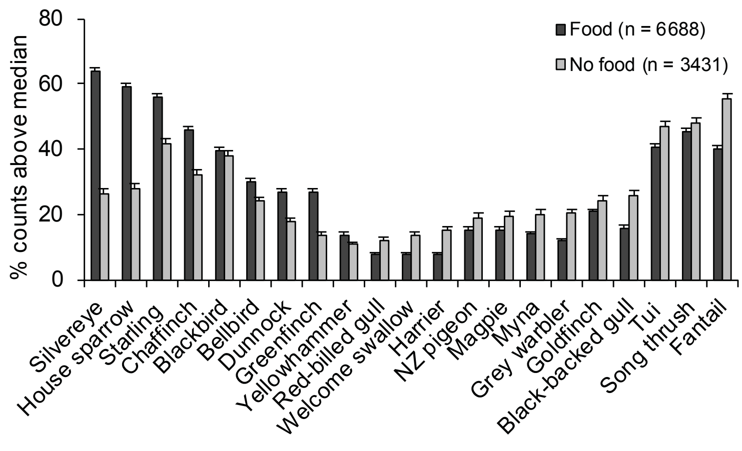


Figure 4. Percentage of counts above the median (± 95% binomial confidence limits) recorded in gardens where supplementary food was provided compared with gardens where it was not, average 2007–2010 (n = number of gardens surveyed). Differences between food and no food significant (*P* <0.05) for all species except blackbird.

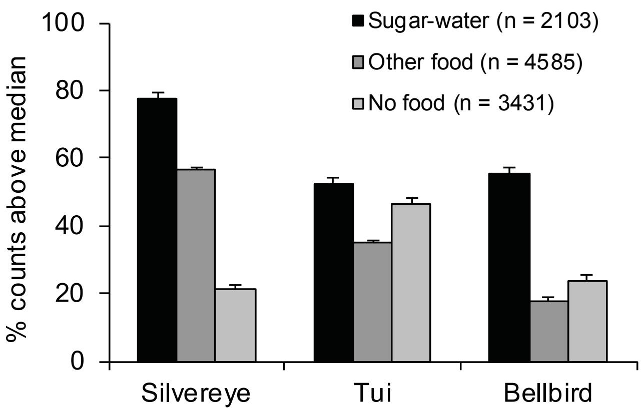


Figure 5. Percentage of counts above the median (± 95% binomial confidence limits) of silvereye, tui, and bellbird recorded in gardens with provision of sugar-water (with and without other food), other food, and no food, average 2007–2010 (n = number of gardens surveyed). Differences between food types significant (*P* <0.05) for all species.

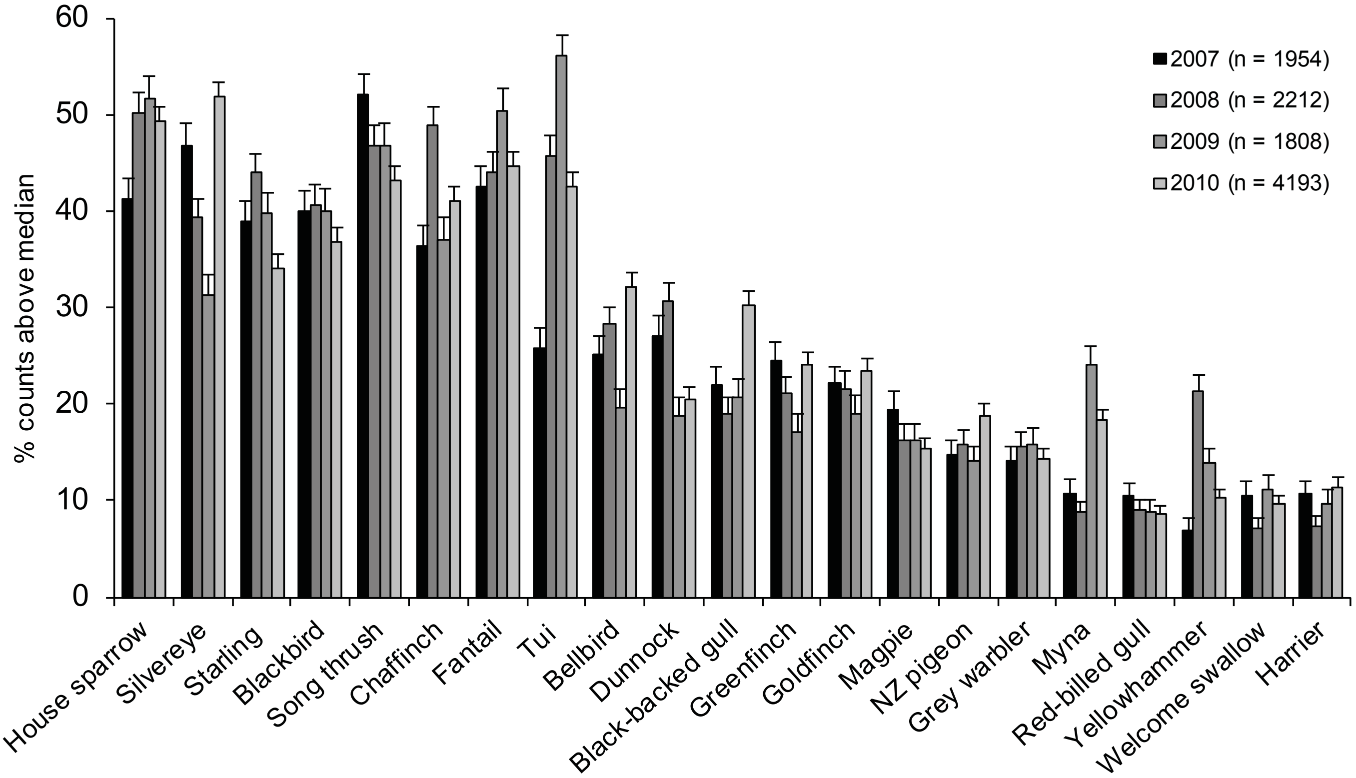


Figure 6. Percentage of counts above the median (± 95% binomial confidence limits) recorded in different years, 2007–2010 (n = number of gardens surveyed). Differences between years significant (*P* <0.05) for all species except grey warbler.

counts declined by 33% nationally from 2007 to 2009 (χ^2 = 158.7, d.f. = 2, *P* < 0.001) and then increased by 66% from 2009 to 2010 (Fig. 6). The decline occurred in most regions, but was greatest in Otago and Southland, and in gardens where supplementary food, especially sugar-water, was provided.

Other species that increased over the 4 years included myna (70%), tui (65%), yellowhammer (47%), and bellbird and New Zealand pigeon (both 28%). Other species that decreased over the 4 years included dunnock (24%), magpie (21%), and song thrush (17%). Greenfinch decreased by 30% from 2007 to 2009 (χ^2 = 35.0, d.f. = 2, *P* < 0.001), then increased by 40% from 2009 to 2010.

Discussion

There have been few previous studies of bird populations in New Zealand gardens, and all have been restricted to one place (e.g. Stidolph 1977; Guest & Guest 1987, 1993; Day 1995; Gibb 2000a,b; van Heezik et al. 2008, 2010; van Heezik & Seddon 2012). The Garden Bird Survey is the first nationwide investigation of garden bird populations, and the first to use volunteers from the general public to collect the data. Many of the volunteers were enthusiastic about the survey and wrote comments on the survey forms, such as 'I discovered several birds that I didn't know visited my garden' and 'I loved doing the survey', indicating that as well as the bird monitoring objectives the educational and fun objectives of the survey were also met. The first four years' data provide new information on the occurrence and abundance of birds in our gardens, and also highlight some potential, though mostly surmountable, problems with the methodology and interpretation of the data.

National occurrence and abundance

Survey participants recorded many more bird species in New Zealand domestic gardens than might have been supposed to occur. This happened because the definition of garden was left to participants to decide. Some confined their observations to a small area within their garden while others (a minority) included surrounding farmland, forest, or even the sea visible from their house or garden. Thus, the range of species recorded included a number not normally detected in gardens. These could have been deleted from the species list, but this would have been to deny that for some people the adjacent farmland, forest, or sea is part of their 'garden'. These species will not feature in analyses of bird population trends because they occur too infrequently.

Blackbird was the most widely occurring species recorded in gardens nationally, and this agrees with the occurrence of bird species in 10 km grid squares in New Zealand compiled by the Ornithological Society (Robertson et al. 2007). However, the national occurrence of other species in gardens and 10 km grid squares was in less agreement. House sparrow, silvereye, and starling were the 2nd, 3rd, and 4th most widely occurring species in gardens in this study but 17th, 4th, and 10th most widely occurring species in 10 km grid squares. This lack of agreement is not surprising because gardens (most less than 2000 m^2) cover a much smaller unit area and also represent only one of the habitat types (i.e. residential) surveyed in Robertson et al. (2007). What is surprising perhaps is that the endemic tui was the 5th most widely occurring species in gardens, at least in winter, but only the 25th most widely occurring in 10 km grid squares in New Zealand as a whole, over the period of the survey. The endemic bellbird was 11th (cf. 20th) and New Zealand pigeon 14th (cf. 27th). This illustrates the potential importance of gardens as a habitat for native bird species, especially as the area of natural habitats declines and native plantings in urban areas increase (Day 1995; Cannon 1999; Chace & Walsh 2006; van Heezik et al. 2008). In addition, winter-flowering adventives in gardens may provide native nectarivorous species such as tui and bellbird with a rich source of food not available in natural habitats.

It can be invalid to compare percentage occurrence or counts (indices of abundance) between species because each species has unique physical and behavioural characteristics that affect its detectability (Johnson 2008). For example, the house sparrow occurs in large flocks and in the open (such as in the middle of lawns) and so is much more conspicuous than the dunnock, which tends to be solitary and secretive, usually keeping close to cover (such as hedges). Likewise, the silvereye occurs in large flocks, at least in winter, and is attracted to supplementary food provided by humans, and so is much more conspicuous than the grey warbler, for example, which is more solitary and usually not attracted to artificial food. Consequently, the occurrence and numbers of dunnock and grey warbler are likely to have been underestimated in comparison with house sparrow and silvereye. Despite this, comparisons between species (both in occurrence and abundance) are still made without accounting for differences in detectability, perhaps mainly for public-relations purposes, as evident from lists of the top 10 most abundant species on garden bird survey websites (e.g. www.rspb.org.uk/birdwatch and www.birdsource.org/gbbc). This is reasonable provided it is acknowledged that what is being compared is what survey participants recorded in their gardens, not necessarily the relative occurrence or relative abundance of species.

House sparrow and silvereye were by far the most numerous species recorded by survey participants nationally in this study. They were also by far the most numerous species recorded in independent surveys in gardens in Hamilton (Day 1995) and Dunedin (van Heezik et al. 2010; van Heezik & Seddon 2012). House sparrow was also the most numerous species recorded in UK gardens in the same four years (www.rspb.org.uk/birdwatch; R. Bashford, RSPB, pers. comm.). Starling, the third most numerous species recorded in gardens nationally, also occurs in flocks and is attracted to supplementary food, making it also one of the more conspicuous species in gardens. Starling was the second most numerous species recorded in gardens in the UK, behind house sparrow, of the species common to the two countries. Blackbird, the fourth most numerous species recorded in gardens nationally, does not occur in flocks, and although attracted to supplementary food and recorded in more gardens than any other species, was recorded in lower average numbers than house sparrow, silvereye, and starling. Blackbird was the third most abundant species recorded in gardens in the UK, of the species common to the two countries. The similarity of species rankings in New Zealand and UK gardens probably reflects the adaptability of these species to the human-developed landscape worldwide (Tratalos et al. 2007; Evans et al. 2011).

Most species in gardens were adventives (introduced species). Silvereye, tui, and fantail were the only native species in the top 10, by occurrence and abundance. Another six native species (bellbird, black-backed gull, red-billed gull, welcome swallow, New Zealand pigeon, and grey warbler) occurred in the top 20. These rankings assume that all species are equally detectable, which as noted above is unlikely to be true. However, the rankings are likely to reflect the approximate order of occurrence and abundance of species in gardens, and indicate the unsuitability of the current human-developed landscape for most native species.

Regional occurrence and abundance

The regional occurrence recorded for some species in gardens matched the regional occurrence recorded in 10 km grid squares in Robertson et al. (2007). For example, myna, tui, fantail, grey warbler, and New Zealand pigeon were recorded in a higher percentage of gardens and in a higher percentage of 10 km grid squares in the North Island than in the South Island. Likewise, bellbird and dunnock were recorded in a higher percentage of gardens and in a higher percentage of 10 km grid squares in the South Island. There were obvious mismatches in the distribution of occurrence of silvereye, starling, chaffinch, greenfinch, and goldfinch, which were recorded in a higher percentage of gardens in the South Island but in a higher percentage of 10 km grid squares in the North Island. These differences may be explained by differences in habitat and scale, as noted above.

Regional differences in the counts (indices of abundance) of some species in gardens were expected, based on regional distributions of occurrence in 10 km grid squares (Robertson et al. 2007). For example, at the time of the survey, tui was sparsely distributed in Canterbury, and bellbird in Northland, Auckland, and Waikato (Robertson et al. 2007), and this was reflected by low counts of these species in gardens in these regions. Likewise, the higher counts of fantail and grey warbler in North Island gardens and dunnock in South Island gardens matched the pattern of their percentage occurrence in 10 km grid squares (Robertson et al. 2007). For these species, there was an apparent relationship between occurrence and indices of abundance – the fewer 10 km grid squares (and fewer gardens) they occurred in, the lower was the average number of birds counted per garden. For other species, there was a closer correlation between regional occurrence in gardens and regional abundance in gardens than between regional occurrence in 10 km grid squares and regional abundance in gardens.

The relative counts of house sparrow and silvereye in gardens in this study agree with the relative abundance of the two species recorded in some other studies. For example, house sparrow was the most numerous and silvereye second most numerous species recorded in gardens in Waikato-Bay of Plenty in this study, and this is consistent with the findings of Day (1995) in Hamilton (Waikato). Silvereye was the most numerous and house sparrow second most numerous species recorded in gardens in Otago, consistent with van Heezik et al. (2010) and van Heezik & Seddon (2012) in Dunedin (Otago). The lower number of house sparrow counted in gardens in Canterbury, Otago, and Southland than in other regions of the country occurred despite a higher percentage of participants in these three southern regions providing birds with supplementary food, including a higher percentage providing bread and seeds. It also occurred both in gardens where birds were fed and in gardens where they were not fed, indicating a latitudinal effect, although this needs further study. Likewise, the higher number of silvereye counted in gardens in Canterbury, Otago, and Southland occurred in gardens where birds were fed and in gardens where they were not fed, again indicating a possible latitudinal effect.

The lower occurrence and lower counts of starling in gardens in northern North Island regions and the inverse relationship with the occurrence and counts of myna may indicate competition between the two species and/or that they have different habitat or environmental requirements. A similar interaction between the two species was recorded in gardens in Canberra, Australia, where starling numbers decreased over a 20-year period as myna numbers increased (Veerman 2003). An inverse relationship between starling and myna occurrence in New Zealand was not evident at the larger spatial scale of 10 km grid squares (Robertson et al. 2007).

Urban compared with rural gardens

Urban gardens, 76% of the returns, were possibly under-represented in the survey because Statistics New Zealand classified 86% of households in New Zealand in 2006 as urban (www.stats.govt.nz). However, what survey participants and Statistics New Zealand considered urban probably differed. The percentages of survey returns from urban compared with rural gardens varied regionally, and from year to year within region, and were not in proportion to the regional numbers of urban compared with rural households (Appendix 3). Ideally, the regional average numbers of each species per urban and rural garden should have been weighted by the proportion of households in each region classified as urban and rural to obtain more representative national averages. However, this was not done here, nor were urban and rural gardens analysed separately by region, partly because of the uncertainty of classification of urban and rural, and partly because of small sample sizes.

The larger number of species, and higher counts of most species, in rural compared with urban gardens is a pattern that also occurs in the UK (Chamberlain et al. 2004; Evans et al. 2009). Two of the species that had higher counts in urban gardens in New Zealand (house sparrow and greenfinch) also had higher counts in urban gardens in the UK (Tratalos et al. 2007; Evans et al. 2009). However, two other species (starling and blackbird) that had higher counts in urban gardens in the UK did not have higher counts in urban gardens in New Zealand (in this study). This may have been partly because some participants in rural areas included surrounding farmland as part of their garden (effectively increasing their garden size), and partly because public parks (mostly urban) were excluded from analyses whereas they were included with domestic gardens in the UK analyses. Parks, probably because they are larger in size, had larger counts of starling and especially blackbird than domestic gardens (www.landcareresearch.co.nz/research/biocons/gardenbird). Rural gardens are probably larger and more diverse than urban gardens, as in the UK (Chamberlain et al. 2004), which likely explains the larger number of species and higher counts of most species in rural gardens. The higher counts of house sparrow, silvereye, and greenfinch in urban gardens were a consequence of supplementary feeding, which occurred more in urban than in rural gardens.

Effects of providing supplementary food

The percentage of survey gardens in which supplementary food was provided for birds (72%) is likely higher than the percentage for all gardens in New Zealand because people who fed birds were probably more likely to have participated in the survey than those who did not. There was no available information on the percentage of households in New Zealand providing supplementary food for birds to use to weight for this factor, so results should be interpreted with caution. In the UK and USA, estimates of the percentage of households providing supplementary food for birds range from 25 to 75% (most more than 50%; Lepczyk et al. 2004; Chamberlain et al. 2005; O'Leary & Jones 2006; Fuller et al. 2008; Jones & Reynolds 2008; Davies et al. 2009; Evans et al. 2009; Jones 2011). Regional differences in the percentage of participants providing supplementary food (e.g. a higher percentage in southern regions) are likely to be at least partly related to climate. Severe winter weather is one of the reasons why people in other countries feed birds (Jones & Reynolds 2008; Jones 2011).

The higher numbers of some species (e.g. house sparrow, silvereye, starling, chaffinch, greenfinch, dunnock, tui, bellbird, and yellowhammer) counted in gardens where supplementary food was provided was expected from other studies (Chamberlain et al. 2004; Fuller et al. 2008; Jones & Reynolds 2008; Evans et al. 2009; Jones 2011). Some researchers have shown that provision of supplementary food can be beneficial to birds by providing additional food in a time of natural food shortage, resulting in earlier and longer breeding and increased productivity (Jones & Reynolds 2008; Robb et al. 2008). However, other researchers have found conflicting results (Harrison et al. 2010). Also, some researchers have noted that the provision of supplementary food may be detrimental to birds by, for example, aiding the spread of disease (Jones & Reynolds 2008; Jones 2011).

Some of the results showing lower numbers of some species counted in gardens with supplementary food may be spurious because the method of analysis did not allow regional data to be weighted by the proportion of households in each region, and assessed only one factor (supplementary feeding). For example, the lower number of tui counted in gardens with supplementary food was strongly influenced by the proportionally large number of survey returns from Canterbury, where supplementary feeding was common but tui rare. On the other hand, the lower counts of harrier, magpie, and swallow were influenced by most gardens with supplementary food being urban and most gardens with these species being rural. However, goldfinch, fantail and grey warbler were recorded in lower numbers in gardens with supplementary food in most regions and in both urban and rural areas. Thus, for these species, the relationship was not an artefact of the interaction between the regional prevalence of supplementary feeding and their abundance. Most likely, the small goldfinch was supplanted at feeders by the larger more aggressive greenfinch. Reduced numbers of small subordinate species in favour of larger more aggressive species has been noted at feeders elsewhere (Parsons et al. 2006; Jones & Reynolds 2008). On the other hand, the insectivorous fantail and grey warbler may have avoided gardens with supplementary food because the large numbers of some other species attracted to the food (e.g. the omnivorous silvereye) had depleted the local invertebrate food supply. Further investigation will be necessary to clarify these relationships.

Changes between years

Changes in the numbers of birds counted nationally from year to year were potentially confounded by annual changes in the proportion of participants by region, because the method of analysis did not allow the data to be weighted. For example, 2007 and 2010 survey returns were predominantly from Canterbury, and 2008 and 2009 returns from Wellington. Thus, the increase in number of house sparrow counted nationally from 2007 to 2008, for example, could simply have been a reflection of the increase in the proportion of returns from Wellington, where the number of house sparrow counted was higher than in Canterbury. However, this was not the explanation in this example because the number of house sparrow counted in Wellington also increased markedly from 2007 to 2008, as it did in most other regions.

Assuming the year-to-year changes in the counts of most species were real, it is too soon to tell whether they were just part of normal fluctuations in numbers over time or part of a long-term trend. For example, the increase in house sparrow counts may have been in response to favourable environmental conditions or may indicate the species is still recovering from an outbreak of salmonellosis in 2000 that caused major mortality in house sparrow populations in many parts of the country (Alley et al. 2002). In contrast to the situation in New Zealand, house sparrow numbers in UK gardens declined by 14% over the same period (2007–2010), a continuation of a decline of about 60% in the last 25 years (R. Bashford, RSPB, UK, pers. comm.). House sparrow numbers in Canberra gardens declined by about 70% over the last 25 years (http://cbn.canberrabirds.org.au). Time will tell if eventually the New Zealand house sparrow population declines similarly.

The cause of the decline in silvereye counts in some regions between 2007 and 2009 could not be determined by the survey, but could have been avian pox. Survey participants in Otago reported seeing diseased birds with growths around their bills, eyes, and legs, symptomatic of avian pox, at sugar-water feeders in 2008. Avian pox was positively identified in silvereye in Dunedin the same year (G. Loh, Department of Conservation, Dunedin, pers. comm.). Spread of disease by the aggregation of large numbers of birds at supplementary food is a known hazard for birds (see above).

Short-term changes in the counts of other species could have been caused by a number of factors. Some participants suggested that increases in tui, bellbird, and New Zealand pigeon counts, for example, were a result of local control of mammalian pests such as the brushtail possum (*Trichosurus vulpecula*), stoat (*Mustela erminea*), and rat (*Rattus* spp.). However, the time frame is too short, and there were no baseline counts and no counts in paired non-treatment areas to be sure of this.

Problems with the method and interpretation of results

Interpretation of the results is potentially influenced by a number of methodological problems. In particular, the gardens sampled were not a random selection of gardens in New Zealand but were self-selected by volunteer participants in the survey who were probably more likely to be interested in birds, more likely to have bird-friendly gardens, and more likely to feed birds than the populace as a whole. Thus, the percentages of gardens in which species occurred and the average numbers of birds of different species per garden were likely higher than in the average New Zealand garden. Volunteer non-random selection of sampling sites ('convenience sampling') also occurs in other bird surveys and has been criticised by some researchers (e.g. Anderson 2001; Dunn et al. 2005) but considered by others not to affect use of the data for monitoring population trends (Gregory et al. 2005; Gregory & van Strien 2010). The safest interpretation is that the current garden bird survey will monitor bird population trends in the gardens of participants but not necessarily in the gardens of New Zealand as a whole.

Garden size, or more correctly the area of observation, was not defined and this could pose a problem for the calculation of bird population trends in the future if the average area of observation changes over time (Meadows et al. 2012). However, the problem may be not as serious as might first seem because most participants counted birds in only part of their garden. The problem could have been avoided by limiting the area of observation to a fixed distance from the observer, or by recording birds in distance bands away from the observer. For example, the observation area in the Canberra Garden Bird Survey is limited to a radius of 100 m (Veerman 2003). This is rather large for New Zealand gardens, and perhaps a radius of 25 or 50 m might be more appropriate. The Big Garden Birdwatch, Garden Birdwatch, and Great Backyard Bird Count do not specify a distance. If average garden size or area of observation does change over time bird counts will need to be weighted to adjust for this.

The bird identification skills of survey participants varied from experts to beginners, and a few species identifications and counts were questionable. As noted, errors have been screened out as much as possible, but probably some are still present. However, the majority of observations by volunteers are likely to be accurate because the species occurring in most gardens are relatively common, limited in number, and familiar to most people (Cannon 1999). Problems might arise in calculation of bird population trends if the average skill of participants changes over time. However, although the skills of individual participants may change, with a large number of participants and new participants joining each year the average skills of all participants are unlikely to change (Snäll et al. 2011).

The relationship between the maximum number of birds detected at any one time in one hour (as an index of abundance) and the true density of birds is unknown. The method ensures that no birds are counted more than once. This is simpler than trying to keep track of all individuals of each species detected over the period of observation, which would be difficult and incur the risk of double counting if the number of species and/or number of individual birds was large. The index is assumed to be linearly proportional to true density.

Indices can be used for comparing abundance and for monitoring population trends within species provided variation in bird detectability between the categories being compared (e.g. between regions, urban and rural, with and without supplementary food, and years) is substantially less than the change in population size one wishes to detect, and provided it is also independent of population size (Johnson 2008). Using distance sampling, van Heezik and Seddon (2012) claimed that for eight out of 10 monitored species there were no differences between detectability of birds in bush fragments, large mature gardens, large structurally simpler gardens, and small gardens comprising mostly lawns and flowerbeds in Dunedin. Distance sampling is not without its problems (Johnson 2008), but on the basis of the above study it seems reasonable to assume that bird detectability within a species will be similar in gardens in different regions of the country, in urban and rural gardens, and from year to year. On the other hand, species that aggregate around supplementary food will likely be more detectable in gardens with supplementary food than in gardens without it. However, most birds probably would not have been in gardens with supplementary food if it was not provided and, although not measured in this study, the increase in their detectability was likely much less than the increase in their number. In the UK, population trends of a number of species obtained from the Garden Birdwatch and Garden Bird Feeding Survey were correlated with population trends from the Breeding Bird Survey (Cannon et al. 2005; Chamberlain et al. 2005). Likewise in North America, trends from Project FeederWatch were correlated with trends from their Breeding Bird Survey (Wells et al. 1998) and the Christmas Bird Count (LePage & Francis 2002). This gives some confidence that variations in

New Zealand garden bird counts accurately reflect variations in true garden bird population density.

A number of other data interpretation problems have already been referred to; for example small sample sizes in some regions, and sample sizes being not in proportion to the number of households (urban and rural) in each region, and probably not in proportion to the number of households providing supplementary food for birds. It will be necessary to weight for these factors in future calculations of long-term national and regional bird population trends, especially if the percentage of participants from urban and rural gardens and from gardens with and without provision of supplementary food changes over time.

Potential uses of the data

Gardens, especially urban gardens, are becoming an increasingly important part of the landscape worldwide (Cannon 1999; Cannon et al. 2005; Evans et al. 2011; Jones 2011). Furthermore, trends in garden bird population indices have been found to reflect trends in bird population indices in the wider environment (Wells et al. 1998; LePage & Francis 2002; Cannon et al 2005; Chamberlain et al. 2005). Consequently, monitoring bird populations in gardens is regarded by some as having increasing value.

An annual garden bird survey in New Zealand has the potential to detect changes in the distribution and abundance of species, including species of concern that might require a management response; e.g. downward trends of native species such as tui and bellbird, or upward trends of adventives such as myna and eastern rosella. It cannot identify the causes of changes but can alert various authorities of the need to investigate them (e.g. disease outbreak, urban development, climate change). It could also provide management agencies, especially city, district, and regional councils, with circumstantial evidence of the success or otherwise of their management actions, such as restoration planting and predator control.

The value of the survey would be increased by randomly selecting gardens, stratified by region, to increase its representativeness at both national and regional scales, in a similar way to the UK Breeding Bird Survey (www.bto.org/volunteer-surveys/bbs), which uses volunteers to count birds in randomly-selected 1 km grid squares. The situation is not quite the same here, however, because owners of randomly selected gardens could not be compelled to participate or to allow volunteers to survey their gardens, so the gardens surveyed might still be largely volunteer-selected. The value of the survey would also be increased by increasing the number of participants, especially in smaller regions, to provide more robust regional population indices, and allow analysis of results by region. If the ratio of the number of gardens surveyed to the total number of households in New Zealand was the same as in the UK, there would need to be about 16 000 gardens surveyed in New Zealand, four times the number that was surveyed in 2010.

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