Manaaki Whenua
Landcare Research

NZ Garden Bird Survey 2017: data editing, analysis, interpretation, visualisation and communication methods

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GARDEN
BIRD
SURVEY

NZ Garden Bird Survey 2017: data editing, analysis, interpretation, visualisation and communication methods

Contract Report: LC3461

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Summary

Purpose of this report

This report summarises the data legacy, editing, analysis, interpretation, visualisation and communication protocols for *State of NZ Garden Birds 2017 | Te Āhua o ngā Manu o te Kāri i Aotearoa*, which are as follows:

- Securing the legacy of the resources required and generated when preparing and publicising the *State of NZ Garden Birds 2017.*
- Editing the raw bird count data ready for analysis.
- Calculating changes in bird counts for a subset of widespread garden birds at national, regional and local scales.
- Using a standardised set of criteria to help the user interpret the results and readily identify changes of potential concern or interest.
- Preparing eye-catching graphics for a non-specialist audience and publicised via multiple channels (media outlets, Facebook, Twitter, email).
- Inviting feedback on the resources from NZ Garden Bird Survey 2018 participants via an online questionnaire.

Data legacy

- Preparing and publicising *State of NZ Garden Birds 2017* require and generate a wide range of valuable resources.
- The benefits of collating those resources and ensuring they have a secure legacy include reduced transaction costs of sharing resources, and evaluating the performance of our communication strategies.
- Using the online DataStore (hosted by Manaaki Whenua – Landcare Research; MWLR), we established two online collections and three groups for storing and sharing NZ Garden Bird Survey (NZGBS) resources with varying levels of access.
- Two different approaches were piloted for documenting the NZGBS protocols, with a basic overview for the data editing steps and a more detailed description for the production of the bar plots.

Source data

- Data were collected by volunteers in gardens nationwide between 2007 and 2017 in the annual NZGBS (i.e. park and school records were excluded).
- Records were classified in relation to Statistics NZ spatial boundary layers (region, urban area, area unit and mesh block). Any duplicates, spatial mismatches, missing information or unusually high bird counts were then removed. Each record was assigned a garden identity, with overlapping records given the same identity and the remainder a new unique identity.
- The edited data set consisted of 31,679 survey records (c. 0.09% to 0.25% of all gardens each year nationally). Most records were gathered from regions with large cities (Auckland, Canterbury, Wellington and Otago).

- Sixteen focal bird species were considered (seven natives, nine introduced). Blackbird (*Turdus merula*), house sparrow (*Passer domesticus*), silvereye (*Zosterops lateralis*) and starling (*Sturnus vulgaris*) had high counts relative to the other 12 species, which often included many zero values.

Trend analysis

- Generalised linear mixed effects models were fitted independently for each species.
- To account for the variation in the number of gardens surveyed, and available for surveying, across locations and spatial scales, the trend estimates were weighted according to the number of gardens available within the respective spatial unit(s).
- The statistical distribution of the weighted trends was determined using parametric bootstrap (n = 1,001 replicates per species).
- The percentage change in bird count estimates (between 2007 and 2017) for each of the weighted bootstrap runs was calculated for each species.
- Model performance was evaluated via a visual inspection of a histogram of the bootstrap replicates relative to the trend estimate derived from the base model. Two species, grey warbler (*Gerygone igata*) and welcome swallow (*Prosthemadera novaeseelandiae*), were excluded from further analyses as their bootstrap distributions were very wide (indicating low precision). For all other species, the bootstrap replicates were bias corrected and re-centred to overlap the point estimates.

Trends of concern or interest

- To understand the significance of the New Zealand garden bird trends from a management perspective, we consider the trend estimates (and their respective confidence intervals) in relation to a specified set of alert thresholds.
- The system seeks to identify rapid (>50%), moderate (≥25% but <50%) and shallow (≥10% but <25%) declines, as well as shallow (>10% but ≤50%), moderate (>50% but ≤100%) and rapid (>100%) increases. It also flags species with little or no change in counts (>10% decline but ≤10% increase).
- The system then evaluates the strength of evidence available for the trend assessment (ranked from insufficient or very weak to very strong). This takes into consideration the percentage of bootstrap estimates that meet the trend threshold criteria and/or that overlap zero. In broad terms, species with lower variability in counts and locations with greater sample sizes will have stronger evidence.
- At the national scale, bird counts have:
    - declined moderately for four species: silvereye, starling, goldfinch (*Carduelis carduelis*) and song thrush (*Turdus philomelos*)
    - undergone a shallow decline for three species: chaffinch (*Fringilla coelebs*), dunnock (*Prunella modularis*) and blackbird
    - changed little or not at all for four: myna (*Acridotheres tristis*), fantail (*Rhipidura fuliginosa*), bellbird (*Anthornis melanura*) and house sparrow
    - undergone a shallow increase for three: kererū (*Hemiphaga novaeseelandiae*), tūī (*Prosthemadera novaeseelandiae*) and greenfinch (*Carduelis chloris*).

- For seven species (silvereye, starling, chaffinch, bellbird, house sparrow, tūī and greenfinch) the evidence for the trend size categorisation was very strong. For the remaining species the strength of evidence ranged from very weak (dunnock, blackbird) to strong (myna, song thrush).

Data visualisation

Results were then tailored for a non-specialist audience using a combination of digital icons, text, graphs, and maps. Our aim was to make these data not only readily accessible but also visually appealing to a non-specialist audience. The online resources include:

- national and regional summary reports (including bar plots and maps)
- interactive data, allowing people to explore their own neighbourhood (Shiny app)
- technical reports with more detailed statistical information (including dot plots)
- an explanation of the analytical methods used behind the scenes.

Three data sets are publicly available on the MWLR DataStore, allowing the user to view, download or embed the resources: summary and technical reports (34 PDF files); bar plots by location (192 images; PNG; ZIP); and species bar plots and maps (28 images; PNG; ZIP).

Communication strategy

- *State of NZ Garden Birds 2017* was also published on the NZGBS web page, with a gallery of thumbnails linking the user to the available resources. This suite of web pages was viewed over 10,000 times between 19 June and 9 July 2018, a five-fold increase on the previous year.
- About 50 items based on our report were published by national and local media outlets, with a total audience reach of over 3.1 million; at least 61% of the items include our 'backyard barometer' concept, and 34% used our graphics or adaptations of them.
- There were nine Facebook posts publicising *State of NZ Garden Birds 2017* in June 2018, reaching 61,600 people and appearing 94,600 times on newsfeeds, with 1,700 reactions, comments or shares in total.
- Two posts on the MWLR Twitter account publicised *State of NZ Garden Birds 2017* (with 19 retweets and 41 likes in total).
- An email announcing the publication of *State of NZ Garden Birds 2017* was sent to 8,680 people on 21 June; about 45% of those emails were opened and about 25% clicked through to at least one of our online resources.

Public awareness and interest in resources

- NZGBS 2018 participants were invited to take part in an online feedback survey to help us improve their experience. Forty-nine percent of respondents (n = 4,213) were aware of the *State of NZ Garden Birds 2017* report (cf. 45% in 2017; n = 2381).
- Of those respondents who were aware of the report, most (70–80%) were aware of and interested in the species maps, regional and species graphs, and regional

summary reports specifically. Over 50% were also aware of, and interested in, the interactive maps and the technical reports.

- Feedback reflected this enthusiasm ('Really great report, easy to read, understand and share') and confirmed how better-resolution information can motivate behavioural change: ' The report was what prompted me to take part, our region was really underrepresented … so myself and others … decided we needed to participate'.

Discussion and conclusions

- By transparently documenting our process for developing *State of NZ Garden Birds 2017* we are building engagement with and trust in the available resources.
- By setting up the online DataStore we can secure the legacy of the wide variety of valuable resources used to prepare and publicise the *State of NZ Garden Birds 2017* resources. However, this requires tailoring the resource infrastructure to the diverse needs and abilities of potential users, which we have successfully piloted.
- By telling a richer story with *State of NZ Garden Birds 2017* we successfully reached a larger, more diverse audience while increasing engagement. However, the report production team require appropriate support to ensure the timely and appropriate delivery of the te reo resources in future years.
- By tailoring our reporting to reach a combination of non-specialist and specialist audiences via different communication channels, we have significantly increased awareness of and engagement with our resources. We have also motivated people to take part in the survey by making locally relevant information available to them.

Recommended next steps

- *Data legacy:* edit, document and load the outstanding resources listed in Table 1 to the online DataStore.
- *Source and edited data:* establish a governance strategy and protocols for sharing data.
- *Trend analysis and interpretation:* investigate the issues flagged in relation to model fit and bootstrapping (in particular for the grey warbler and welcome swallow), and invite a panel review of the approach to finalise and establish current protocols as the standard.
- *Data visualisation and communication* – capability is required to support the review and publication of te reo resources in future years: invite a stakeholder review of resources to determine whether further refinement of these resources is required to make them useful and relevant.
- *Communication strategy:* work more closely with stakeholders to build on the success of this year's strategy and educate them about the level of effort required to build engagement.

1 Introduction

1.1 Purpose of this report

This report summarises the data legacy, editing, analysis, interpretation, visualisation and communication protocols for *State of NZ Garden Birds 2017 | Te Āhua o ngā Manu o te Kāri i Aotearoa,* which are as follows:

- Securing the legacy of the resources required and generated when preparing and publicising the *State of NZ Garden Birds 2017.*
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1.2 Value of biodiversity monitoring

The value of biodiversity monitoring has been clearly demonstrated in recent years for documenting ecosystem change (Both & Visser 2001; Devictor et al. 2008; Anderson et al. 2011), engaging public awareness in environmental issues, and providing the necessary evidence base for conservation legislation (Butchart et al. 2010). For example, population monitoring demonstrating farmland bird decline in the United Kingdom (Siriwardena et al. 1998; Krebs et al. 1999; Chamberlain et al. 2000; Fewster et al. 2000) provided the basis for:

- successfully engaging media and public interest (Gregory et al. 2004)
- motivating targeted research to understand the mechanisms of decline, and thus identifying approaches to reverse decline (Peach et al. 2001; Hole et al. 2002)
- putting in place initiatives to foster the uptake of management solutions by farmers (Wilson et al. 2010).

The need for more effective and interacting long-term monitoring programmes is thus being advocated:

> *it is now increasingly critical to undertake high-quality, question-driven, statistically-designed monitoring, given the rapid increase in the effects of climate change, other human-accelerated environmental changes, and the need to reverse current, widespread environmental degradation. (Lindemayer & Likens 2010, p. 1318)*

The NZ Garden Bird Survey (NZGBS) is a citizen science initiative, coordinating volunteers around the country to survey (count, by species) birds in their gardens, parks and schools in midwinter using a standardised protocol (Spurr 2012). As the country's longest-running survey of biodiversity in urban and rural landscapes at the national scale, it acts as a 'backyard barometer', telling us about the health of the environment we live in. Birds are

targeted because they are relatively easy to observe and identify, they are an iconic component of biodiversity, and they are good indicators for assessing other taxa and ecosystem services (Furness & Greenwood 1993; Newton 1998; Pereira & Cooper 2006). By focusing on birds, which people have more affinity with than other taxa (such as insects), the NZGBS helps to increase public awareness and engagement in environmental monitoring and management, as well as helping other stakeholders (e.g. government agencies and community groups) to meet their own environmental monitoring and management goals.

1.3 Benefits of our analytical approach

We use recent advances in statistical modelling techniques to cost-effectively calculate consistent and robust metrics at multiple spatial scales (MacLeod et al. 2015). The analyses use the national data set and explicitly account for variation in sampling effort over space and time using the full data set (i.e. fitting models at the garden level rather than modelling based on derived national or regional averages). This provides several advantages, including comparable metrics can be derived simultaneously (from the same model) for reporting at national, regional and local scales; and greater precision of derived metrics is facilitated by drawing on the national data set.

2 Data legacy: building supporting infrastructure

Preparing and publicising *State of NZ Garden Birds 2017* requires a wide range of resources, and this process also generates a variety of valuable resources (Table 1). A key challenge is collating those resources and ensuring they have a secure legacy. The advantages of building a more transparent and robust infrastructure for this purpose include a reduction in the transaction costs of sharing these resources (both internally and externally), and the ability to evaluate the performance of current and future communication strategies to engage the New Zealand public.

2.1 Benefits of the online DataStore

The online DataStore hosted by Manaaki Whenua – Landcare Research (MWLR) has the potential to address these challenges because it provides:

- the ability to store a wide range of resources (graphics, data, protocols, reports and links), as well as the capability for users to download and embed the resources elsewhere
- the functionality to document, for each resource, data licence requirements, authorship and other relevant metadata, all of which can be readily updated as required
- the potential to streamline our data analysis and management processes using an Application Programming Interface (API) to interact with some data resources and files in the future (e.g. via the ckanr package in the free software environment R; Chamberlain 1995)
- the ability to group data to make it easier for the user to find relevant information quickly.

Table 1. Types of resources required for each step in the production *State of NZ Garden Birds 2017* and to evaluate the impact of its publicity, the development status and a description of each resource, along with its DataStore specifications (collection and access)

Step	*Resource type*	*Citation*	*Resource development stage*		*DataStore specifications*	
			Status	*Description*	*Collection*	*Access*
Source data	Partially edited data 2007–2015	Spurr 2018	Incomplete	Loaded but not documented	Restricted NZGBS	Limited
	Raw data for 2016 and 2017	Spurr et al. 2018a, 2018b	Complete	Files loaded	Restricted NZGBS	Limited
	Data editing protocols for 2005–2015	Howard et al. 2017	Incomplete	Protocols and associated files are edited but need documenting and loading	Restricted NZGBS	Limited
	Data editing protocols for NZGBS 2016 and 2017	MacLeod et al. 2017; MacLeod, Brandt et al. 2018	Complete	Protocols and associated files edited, documented and loaded	Restricted NZGBS	Limited
Trend analysis	Data analysis protocols, input and output files	Howard et al. 2018	Incomplete	Protocols and associated input and output files require documentation and loading	NZGBS	Internal; make public in future
Trends of concern or interest	Data interpretation protocols, input and output files		Incomplete	Protocols and associated files require editing, documentation and loading	NZGBS	Internal; make public in future
Data visualisation	Core NZGBS graphics (logos, icons, branding protocols)	Rodríguez Estrada et al. 2016; Rodríguez Estrada & MacLeod 2016; Wanrooy et al. 2016	Complete	Ready for review by MWLR graphics and digital teams	NZGBS	Internal; make public in future
	Protocols for generating bar plots, maps, dot plots, reports and an interactive app	MacLeod 2018	Incomplete	Bar plot protocol ready for publication; other protocols require editing, documentation and loading	NZGBS	Internal; make public in future
	Output species and spatial graphics, reports and interactive app	MacLeod, Green et al. 2018; MacLeod et al. 2018a, b, c	Published	All files available on DataStore or shiny app platform	NZGBS	Public
Communication strategy	Social media and web page data		Incomplete	Associated files require editing, documentation and loading	NZGBS	Internal only
Public awareness and interest	Questionnaire design and response data		Incomplete	Associated files require editing, documentation and loading	NZGBS	Internal only

2.2 Infrastructure developments and pilot testing

We established two NZGBS collections and three groups for storing and sharing resources. The collections are:

- the *Restricted NZGBS Collection*[1] (seven data sets), which is used for data that include sensitive information, with only key NZGBS personnel and the DataStore manager allowed access to these resources
- the *NZ Garden Bird Survey Collection*[2] (31 data sets), which has various access levels:
  - resources that are publicly available
  - resources that are visible to a subset of account holders, some of whom can only view the resources and others who can edit them.

Using the 'Groups' function within DataStore allowed the user to be directed to the subset of resources most relevant to them:

- *NZGBS Graphics*:[3] core graphics such as logos, icons, branding protocols (currently 17 data sets)
- *NZGBS Live*:[4] the last results and resources to support the current campaign (currently four data sets)
- *NZGBS Archive*:[5] NZGBS results from previous years and other resources (currently five data sets).

The NZGBS resources used to produce the report are in different stages of development (Table 1). The most advanced suite of resources are the core NZGBS graphics, which are all loaded and ready for review by the MWLR graphics and digital teams before assigning the relevant data licences and publishing them.

Two models for documenting data protocols were piloted.

- *Protocol overview*: using the NZGBS 2016 and 2017 data editing protocols as test cases, we produced a report for each year, which directs the user to the relevant R-code, and input and output files, to complete each step of the protocol.
- *Detailed protocol*: using the NZGBS 2016 and 2017 bar plot protocols as examples, we developed a report for each year that directs the user to all the relevant resources required to produce the bar plot, as well as a detailed explanation for developing the graphics and how to adjust the graphics specifications.

[1] https://datastore.landcareresearch.co.nz/organization/restricted-nzgbs

[2] https://datastore.landcareresearch.co.nz/organization/nz-garden-bird-survey

[3] https://datastore.landcareresearch.co.nz/group/nzgbs-graphics

[4] https://datastore.landcareresearch.co.nz/group/nzgbs-live

[5] https://datastore.landcareresearch.co.nz/group/nzgbs-archive

3 Source data

Annual NZGBS records were gathered by volunteers nationwide between 2007 and 2017. The raw data used to produce this report are all stored in the restricted NZGBS collection on the MWLR online DataStore (Table 1).

3.1 Data editing

Data for the period 2007–2016 were edited using a combination of manual and automated processes (Table 1; Howard et al. 2018; MacLeod, Brandt et al. 2018); data for 2017 were edited using standardised protocols in R (MacLeod et al. 2018c). The data editing protocols and associated output files for 2016 and 2017 have been fully documented and loaded to the online Restricted NZGBS collection ready for use in the future (Table 1).

NZGBS records for all years were classified according to their respective year's Statistics NZ spatial boundary layers (region, urban area, area unit and meshblock; Figure 1). These data were then edited to flag and remove duplicate records; mismatches between spatial location information provided by participants and the Statistics NZ layers; records with missing information; or unusually high counts.

Only records for gardens were selected from the edited data set for trend analysis (i.e. park and school records were excluded). Each record was then assigned a garden identity (n = 19,491) using a standardised set of rules, with garden records overlapping those from previous years being given the same identity and the remainder assigned a new unique garden identity.

Our edited data set included 31,679 garden survey records completed nationwide between 2007 and 2017. The number of records per year ranges from 1,387 to 3,998, equivalent to 0.09% to 0.25% of all New Zealand gardens per year (Table 2).

3.2 Variation in sampling effort

Sampling effort varied across both regions and years within regions (Figure 2). Regions with large cities (Auckland, Canterbury, Wellington and Otago) tended to contribute more observations than other areas, which is also evident when considering the sampling effort in urban areas (Figure 3).

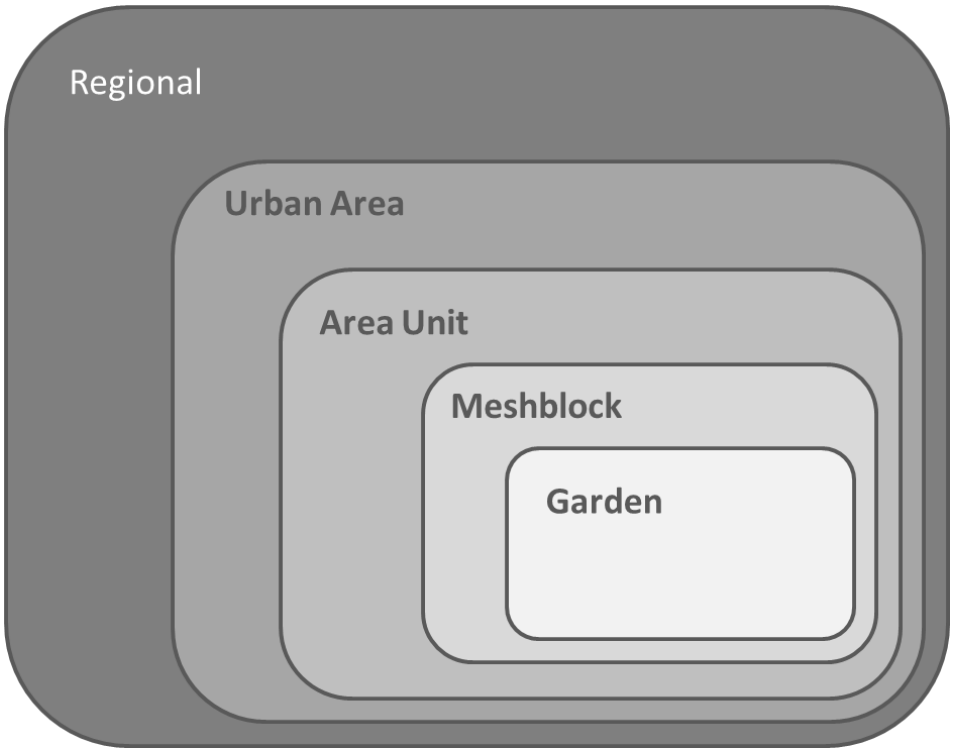


Figure 1. The different spatial scales considered in the NZGBS data analysis.

Table 2. Number of records per year in the edited NZGBS data set (2007–2017) and percentage of households that participated, where the number of gardens was determined by the number of occupied dwellings (*n* =1,570,695; Statistics NZ 2013 Census[6])

Year	*Number of records*	*Percentage of gardens*
2007	1,387	0.09
2008	1,982	0.13
2009	1,688	0.11
2010	3,998	0.25
2011	2,953	0.19
2012	3,791	0.24
2013	3,444	0.22
2014	3,147	0.20
2015	3,482	0.22
2016	3,088	0.20
2017	2,737	0.17

[6] http://archive.stats.govt.nz/Census/2013-census/profile-and-summary-reports/quickstats-about-housing/occupied-unoccupied-dwellings.aspx (accessed 29 May 2018).

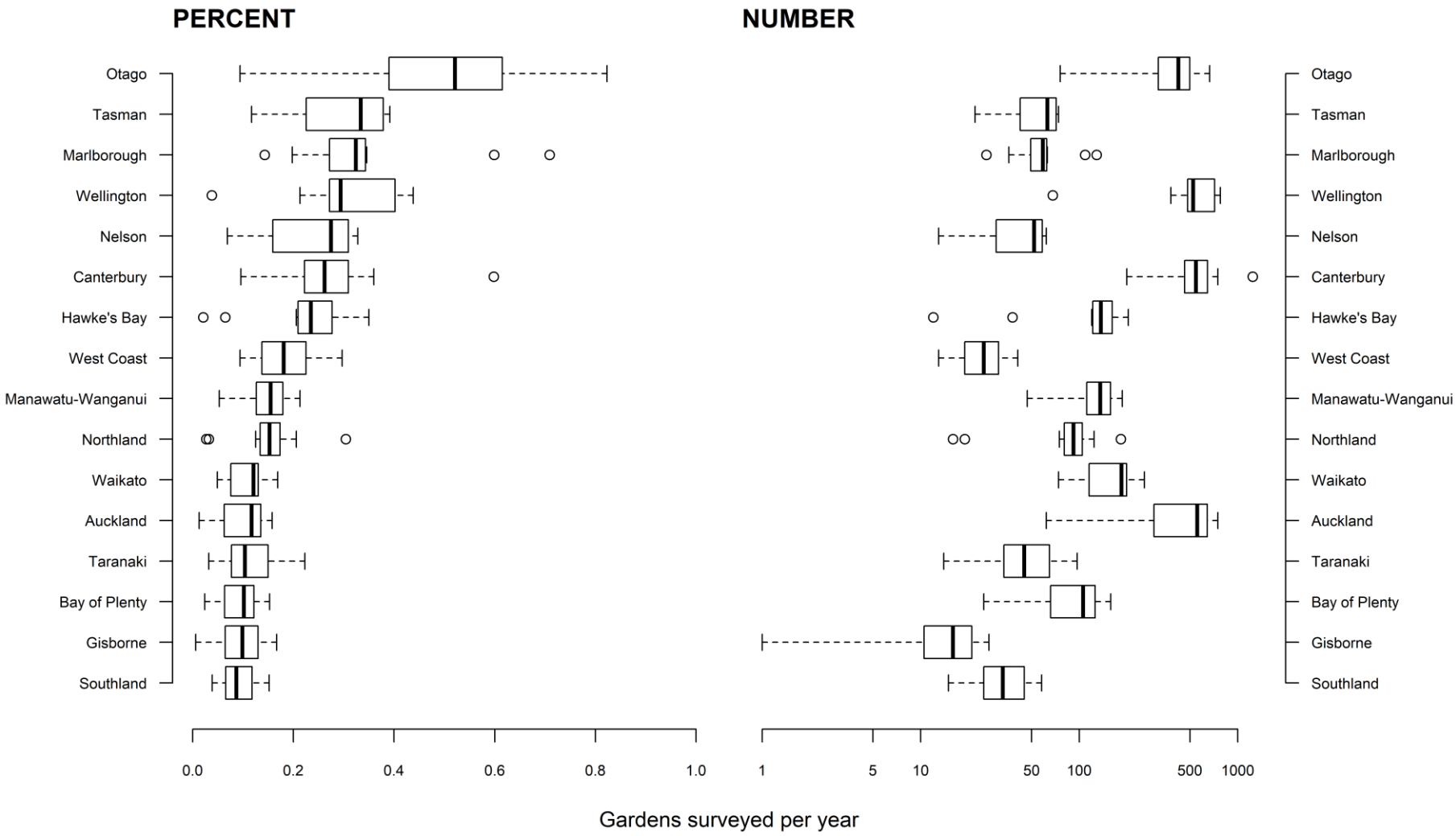


Figure 2. Variation among years (*n* = 11) in the percentage and total number of gardens sampled within each region. Boxes contain the 25th and 75th percentiles, and the line within the box is the median. The whiskers extend to the most extreme data point (which is no more than 1.5 times the interquartile range from the box), and outlier points show the minimum and maximum values.

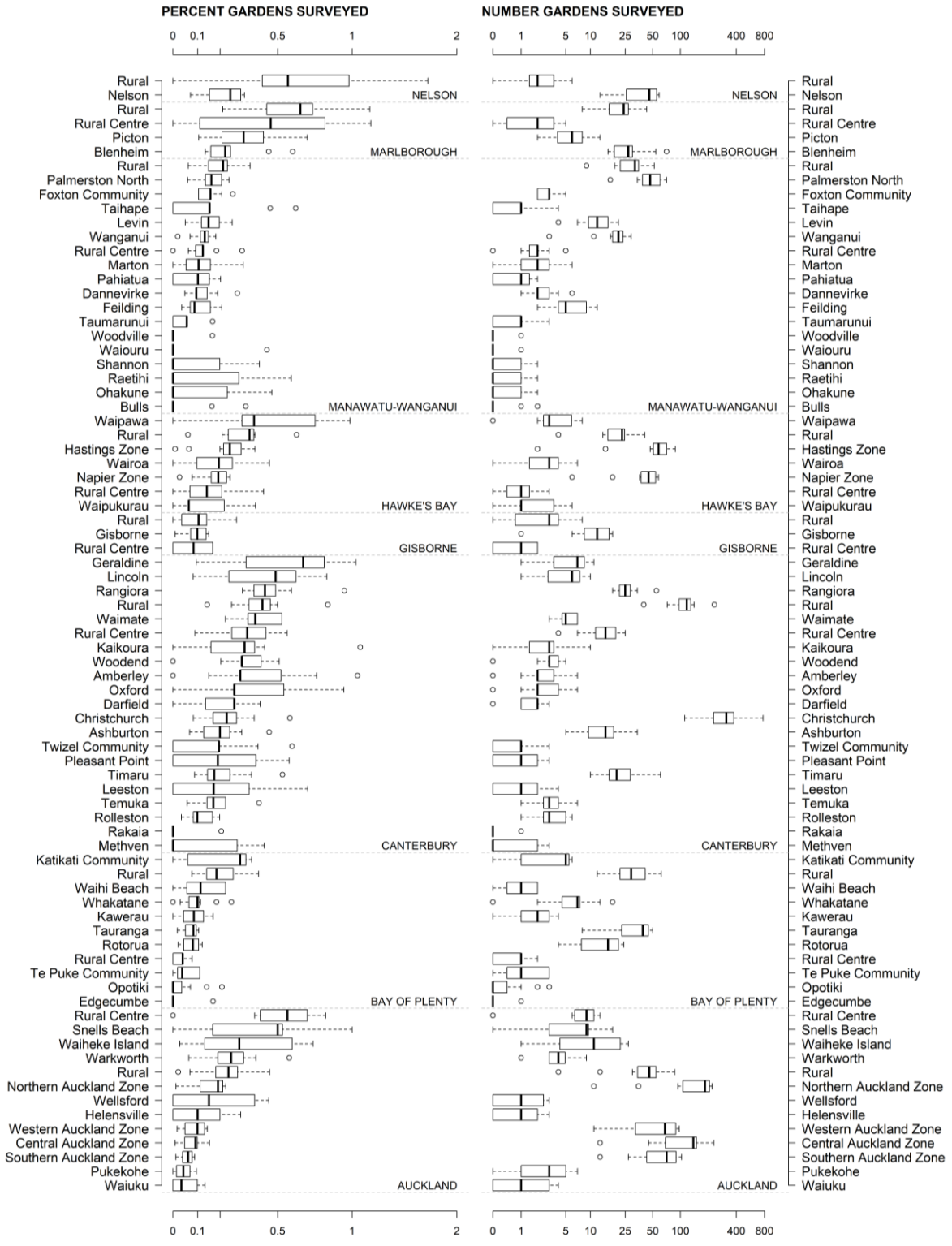


Figure 3. Variation among urban areas (as defined by the Statistics NZ urban area layer) in the number of gardens surveyed within each urban area over 11 years, by region (Note: 'Rural (Incl. some Off Shore Islands)' level is abbreviated in this figure to 'Rural'). Boxes contain the 25th and 75th percentiles and the line within the box is the median. The whiskers extend to the most extreme data point (which is no more than 1.5 times the interquartile range from the box), and outlier points show the minimum and maximum values.

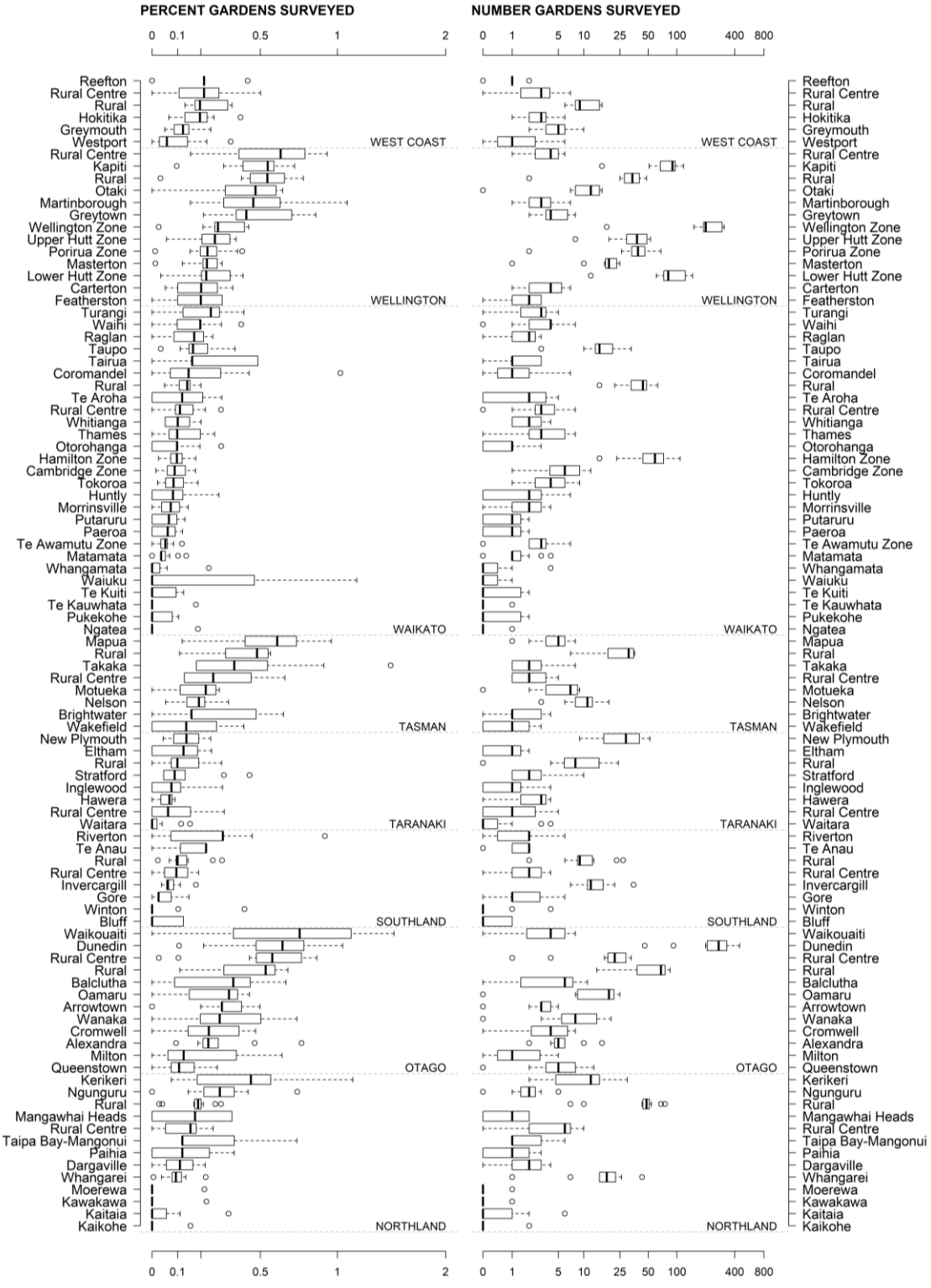


Figure 3 (continued)

3.3 Focal species

Our analysis is of 16 common and widespread bird species (Table 3). Summary box plots of the NZGBS bird counts highlight differences in the data characteristics among the species (Figures 4 & 5). Blackbird, house sparrow, silvereye and starling have high counts relative to the other 12 species, which often included many values of zero (i.e. gardens in which the species was not recorded).

Table 3. Sixteen common garden bird species considered for the NZGBS 2007–2017 trend analyses, with the common and Māori names used for NZGBS reporting

Origin	*Latin name*	*Common name*	*Māori name*
Native	*Anthornis melanura*	Bellbird	Korimako
	Rhipidura fuliginosa	Fantail	Pīwaiwaka
	Gerygone igata	Grey warbler	Riroriro
	Hemiphaga novaeseelandiae	New Zealand pigeon	Kererū
	Zosterops lateralis	Silvereye	Tauhou
	Prosthemadera novaeseelandiae	Tūī	Kōkō
	Hirundo neoxena	Welcome swallow	Warou
Introduced	*Turdus merula*	Blackbird	Manu pango
	Fringilla coelebs	Chaffinch	Pahirini
	Prunella modularis	Dunnock	
	Carduelis carduelis	Goldfinch	
	Carduelis chloris	Greenfinch	
	Passer domesticus	House sparrow	Tiu
	Acridotheres tristis	Myna	Maina
	Turdus philomelos	Song thrush	
	Sturnus vulgaris	Starling	Tāringi

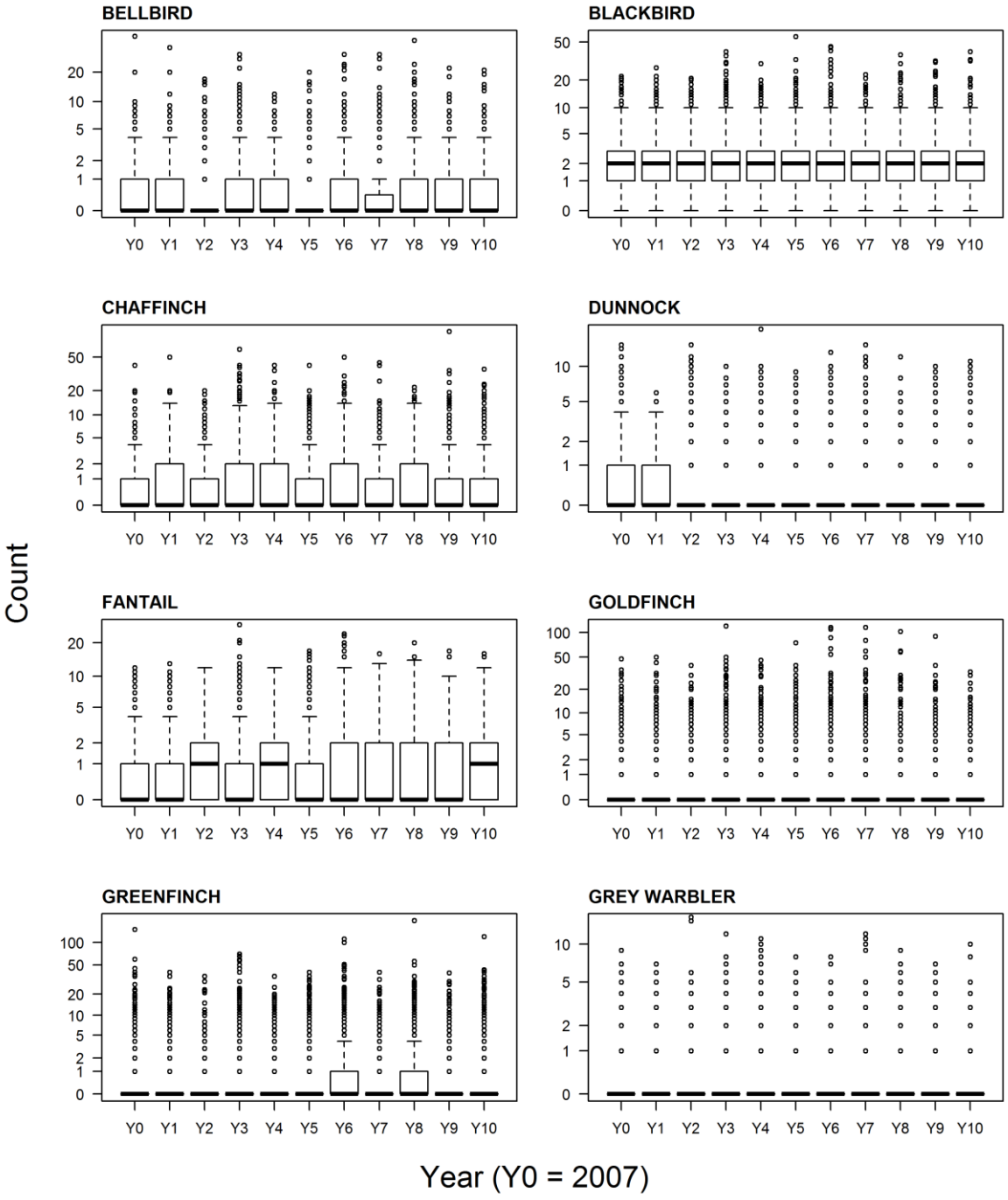


Figure 4. Box plots of bird counts for bellbird, blackbird, chaffinch, dunnock, fantail, goldfinch, greenfinch and grey warbler. Data are presented for an 11-year period, from 2007 (Y0) to 2017 (Y10) (see Table 2 for number of garden surveys per year). Boxes contain the 25th and 75th percentiles and the line within the box is the median. The whiskers extend to the most extreme data point (which is no more than 1.5 times the interquartile range from the box), and outlier points show the minimum and maximum values.

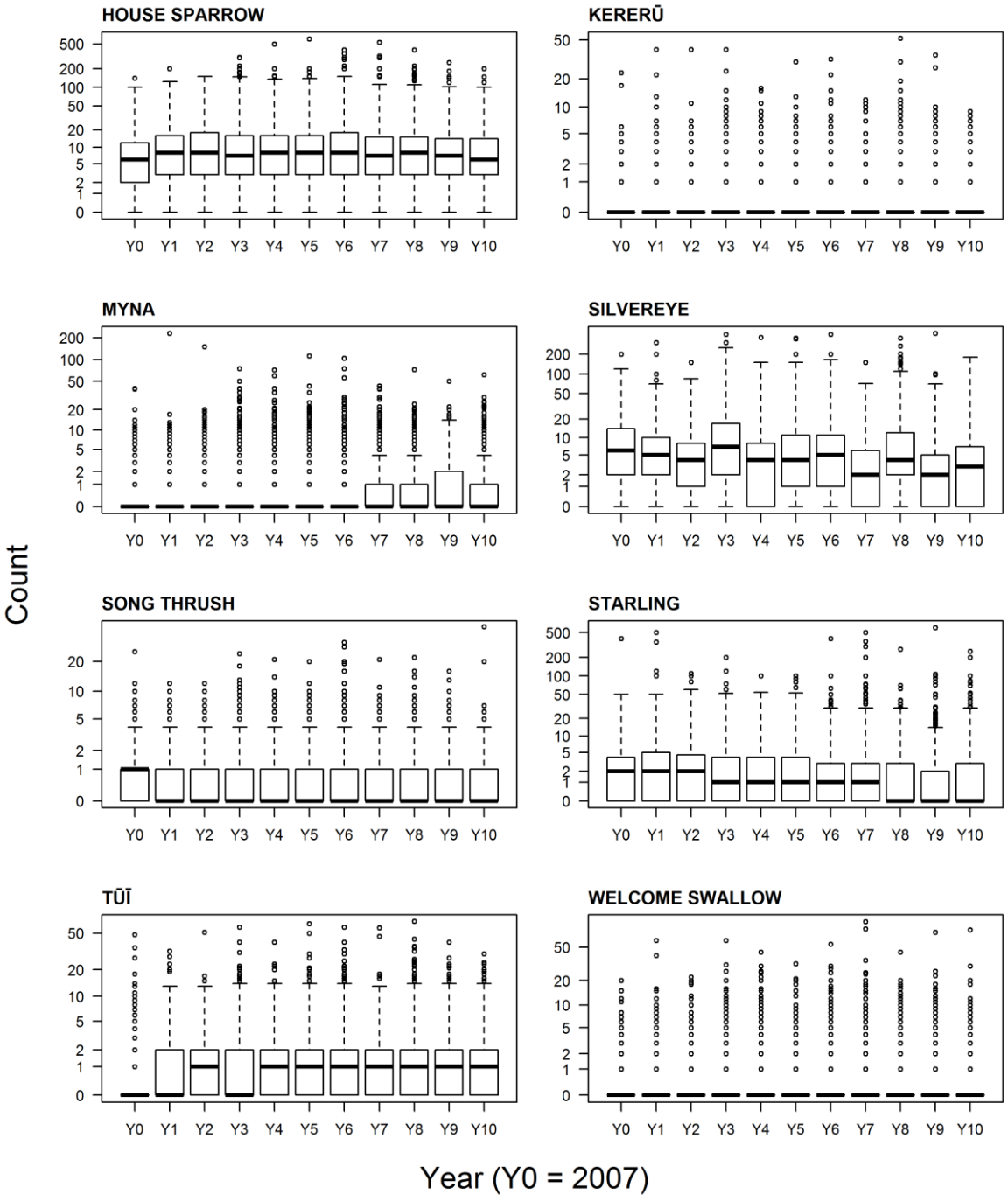


Figure 5. Box plots of bird counts for house sparrow, kererū, myna, silvereye, song thrush, starling, tūī and welcome swallow. Data are presented for an 11-year period, from 2007 (Y0) to 2017 (Y10) (see Table 2 for number of garden surveys per year). Boxes contain the 25th and 75th percentiles and the line within the box is the median. The whiskers extend to the most extreme data point (which is no more than 1.5 times the interquartile range from the box), and outlier points show the minimum and maximum values.

4 Trend analysis

Our analysis estimates changes in NZGBS counts for the period 2007 to 2017 for 16 common garden birds at national, regional, urban area, and area unit levels. This analysis protocol consisted of five key steps:

1 specify and fit the base models

2 calculate weighted trend estimates in relation to the number of gardens at each scale

3 use parametric bootstrap to quantify uncertainty in the trend estimates

4 estimate percentage change in counts

5 evaluate model performance.

4.1 Base model specifications

We used generalised linear mixed effects models to test for a linear trend in the occurrence (presence/absence) or abundance (count) of each species. These models account for repeated measures gathered from spatially nested units (Table 4). Models were fitted for each species independently using the glmer function in the lme4 package (Bates et al. 2015) in R (R Core Team 2018).

Table 4. Models fitted to the NZGBS data for the 16 focal bird species to account for spatial variation in sampling effort across years, as well as variation in garden composition

Response variable	***Fixed and random effect specifications***	***Error distribution***
Presence/absence	~ yS + fUrb * fFed + (yS|R) + (yS|RU) + (yS|RUA) + (1|RUAG)	Binomial
Count	~ yS + fUrb * fFed + (yS|R) + (yS|RU) + (yS|RUA) + (1|RUAG)) + (1|obs)	Poisson

Note: see text for model component definitions.

The sampling unit was the garden, with the presence/absence ('PA') or bird count ('Count') for each of the 16 focal species specified as the response variable. Poisson error distributions were specified for the species with high counts that are skewed (blackbird, house sparrow, silvereye and starling); for all other species, which had relatively low counts, binomial error distributions were specified (Figures 4 & 5).

The fixed effects specified were:

- the year of the survey ('yS', continuous on a standardised scale from –5 to 5)
- categorial terms for garden type ('fUrb', two factor levels: urban and rural)
- bird feeding ('fFed', two factor levels: Yes/No)
- an interaction between 'fUrb' and 'fFed'.

To account for the spatial variation in the presence or the number of birds, all models included random intercepts for four spatially nested variables (Figure 1):

- region ('R', 16 factor levels)
- urban area ('U', 174 factor levels)
- area unit ('A', 1,690 factor levels)
- garden identity ('G': 1,9491 levels).

To account for spatial variation in trends at three scales (region, urban area and area unit), a random slope (with respect to 'yS') was included at each of these levels. Random slopes were not included per garden because there were insufficient data at this level. A binomial response was specified for models fitted to presence/absence data, and Poisson models were fitted to count data. The latter included an over-dispersion term ('1|obs') to account for the large number of zero[7], small, and high counts in the response variable. See Table 4 for detailed model specifications.

4.2 Weighting

Trend estimates from our base models assume a 'balanced survey design'. This means the national trend estimates derived from our base models are equally weighted means of the regional trend estimates, which in turn are based on equally weighted means of the urban area trend estimates, etc.

In practice, however, the NZGBS has an unbalanced design, where the number of gardens surveyed and available for surveying varies between locations and spatial scales. To take this unbalanced design into account, our trend estimates were weighted using a three-step process.

1 The fitted trends were calculated for each area unit by adding the intercepts and slopes for the area unit ('yS|RUA') to the fixed effects for the garden type ('fUrb') and bird feeding ('fFed'). For each area unit, the 'fFed' term was set to the proportion of surveyed gardens where bird feeding occurred; the 'fUrb' term was specified as 0 and 1 for rural and urban area units, respectively.

2 The area unit trend estimates were weighted according to the number of gardens[8] within the unit (as a proportion of the national total[8]).

3 Urban area, region and national trend estimates were derived by calculating the weighted averages of the relevant subset of area units.

[7] https://statisticalhorizons.com/zero-inflated-models

[8] Where the number of gardens was assumed to be proportional to the number of occupied dwellings as determined by the Statistics NZ 2013 Census.

4.3 Parametric bootstrap

Estimating uncertainties (or confidence intervals) in weighted trend estimates is not straightforward, so we used parametric bootstrap.[9] Using the fitted based model as a starting point, we simulated new data, and repeated the mixed model fitting and weighted trend calculation based on the simulated data. By repeating this process (n = 1,001 replicates), we were able to get an estimate of the statistical distribution of the weighted trends. These sampling distributions can be used to estimate the bias and variance of the trend estimates. This bootstrapping process is computationally intensive, taking between 1.5 and 12 hours to run per species on the Google Cloud Platform[10] (24 cores vCPU, 90 GB memory; Table 5).

Table 5. Time taken to run a single bootstrap run, and then projected and actual times taken for 1,001 bootstrap runs using 24 cores per species on the Google cloud. The projected estimate is the base-model running time multiplied by 1,001

Species	***Error distribution***	***Base model***	***1,001 bootstrap simulations***	
			Projected	*Actual*
Bellbird	Binomial	2 m 9 s	1 h 30 m	3 h 46 m
Blackbird	Poisson	6 m 44 s	4 h 43 m	6 h 12 m
Chaffinch	Binomial	3 m 9 s	2 h 12 m	2 h 18 m
Dunnock	Binomial	3 m 4 s	2 h 9 m	3 h 29 m
Fantail	Binomial	3 m 18 s	2 h 19 m	2 h 55 m
Goldfinch	Binomial	3 m 13 s	2 h 15 m	2 h 21 m
Greenfinch	Binomial	3 m 56 s	2 h 45 m	3 h 55 m
Grey warbler	Binomial	5 m 49 s	4 h 4 m	6 h 54 m
House sparrow	Poisson	8 m 28 s	5 h 56 m	7 h 52 m
Kererū	Binomial	2 m 7 s	1 h 29 m	3 h 9 m
Myna	Binomial	1 m 31 s	1 h 4 m	2 h 46 m
Silvereye	Poisson	4 m 49 s	3 h 22 m	5 h 24 m
Song thrush	Binomial	2 m 15 s	1 h 34 m	1 h 28 m
Starling	Poisson	4 m 31 s	3 h 10 m	5 h 44 m
Tūī	Binomial	1 m 50 s	1 h 17 m	2 h 56 m
Welcome swallow	Binomial	1 m 40 s	1 h 10 m	11 h 53 m

[9] Bootstrapping is a resampling technique used to obtain estimates of summary statistics

[10] https://cloud.google.com/compute/docs/faq

4.4 Percentage change in bird counts

The metric for reporting on New Zealand garden bird population trends was the percentage change in bird counts for any given time period and spatial scale. This metric was selected for two reasons: (1) it is comparable across the two types of data considered in our analyses (binomial and Poisson); and (2) it is easier to communicate, and for people to understand, than the slope estimates derived from the models (the metrics previously considered for reporting in MacLeod et al. 2015).

For each of the focal species (s), we calculated the percentage change in bird count estimates (Δy) for each of the weighted bootstrap runs (i):

$$\Delta y_{si} = \left(\frac{y_{sin}}{y_{si1}} - 1\right) * 100$$

where y_{sin} is the bird count estimate for the latest year of the NZGBS (which in our case is 2017) and y_{si1} is the bird count estimate for the first year of the NZGBS (2007).

4.5 Model diagnostics

Model performance was evaluated using a visual inspection of the diagnostic plots, which were histograms showing the bootstrap replicates relative to the trend estimate derived from the base model (i.e. the 'true value' that we are simulating based on the estimated model parameters). Ideally the histogram will be narrow and centred on the true value to indicate precision and unbiased results, respectively. When the histogram departs from this ideal, it is diagnostic of an issue with the estimator, and is unlikely to be a model mis-specification because we are refitting the same model we originally simulated from.

For each species, weighted point estimates (derived from the base model), raw weighted bootstrap replicates ('raw boot'), and bias-corrected bootstrap replicates ('bias-corr') are shown as vertical lines, grey and red histograms respectively in Figure 6. The bias-corrected bootstrap replicates re-centred to overlap the point estimates are shown as yellow histograms ('test boot').

Our histograms depart from the ideal – a narrow 'raw boot' histogram (indicating precision) and centred on the true value (unbiased) – indicating an issue with the estimator that requires further investigation. To address this issue for the purposes of this report, we re-centred the bias-corrected bootstrap replicates ('test boot') to overlap the point estimates. A visual inspection of these plots shows that for all but two species (grey warbler and welcome swallow) the histogram distributions are relatively narrow and approximately centred on the point estimates. Grey warbler and welcome swallow, which had very wide distributions, were therefore excluded from the current analyses.

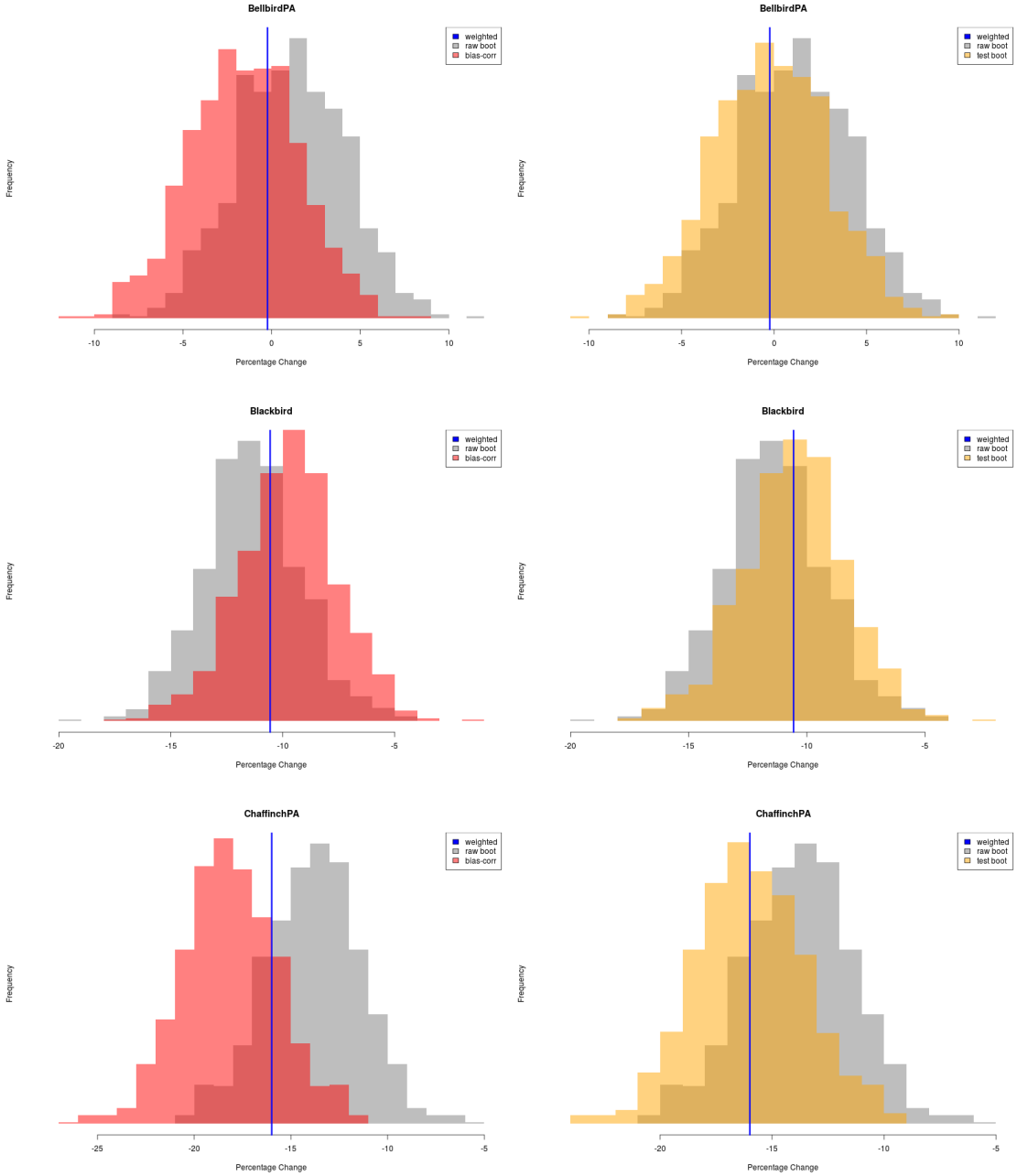


Figure 6 (continued following pages). Diagnostic plots for each species showing the weighted point estimates (derived from the base model; blue vertical lines), raw weighted bootstrap replicates ('raw boot'; grey histograms) and bias-corrected bootstrap replicates ('bias-corr'; red histograms) as well as the bias-corrected bootstrap replicates re-centred to overlap the point estimates ('test boot'; yellow histograms). Note that the x axis scaling varies widely among panels.

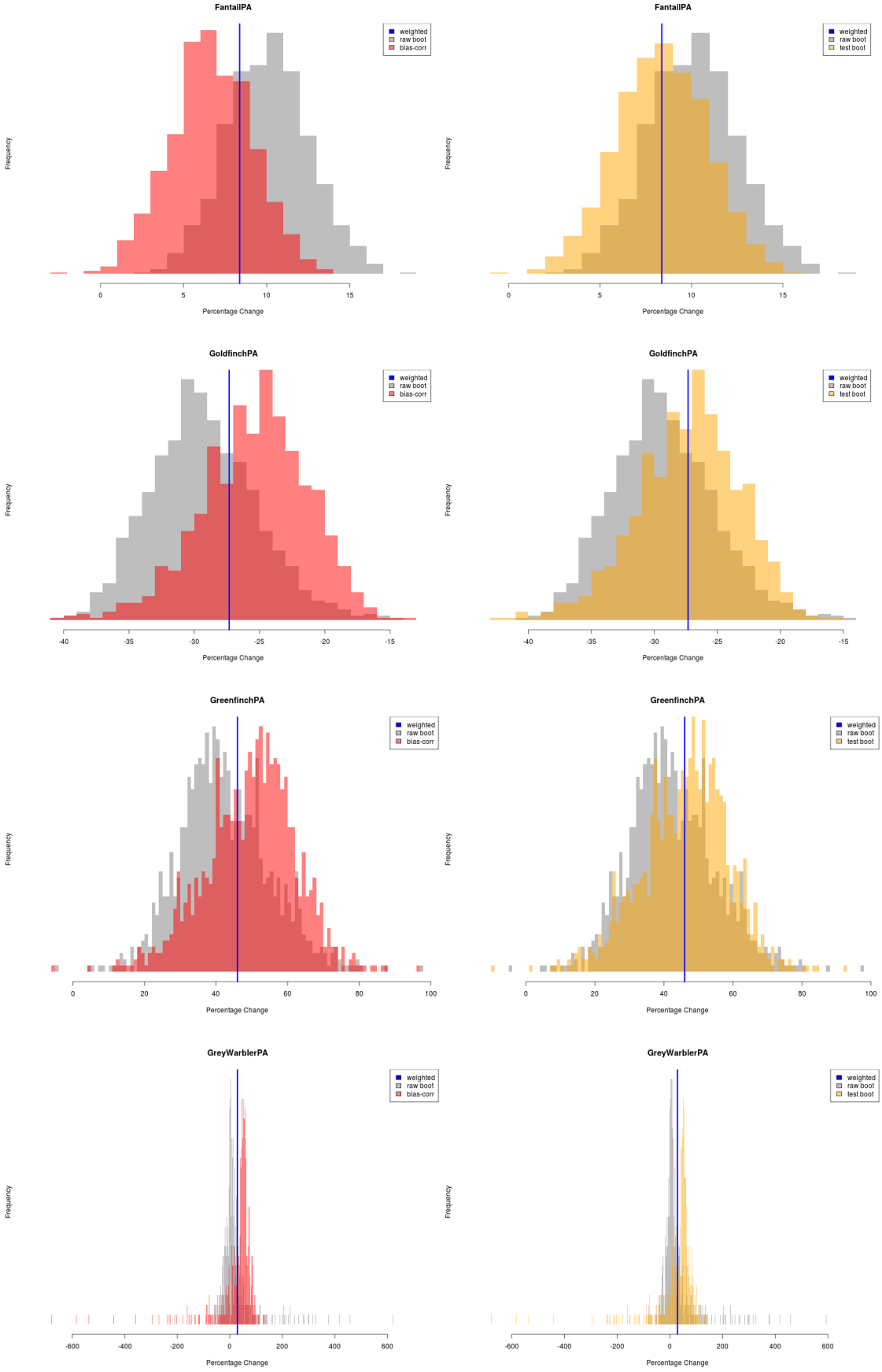


Figure 6 (continued)

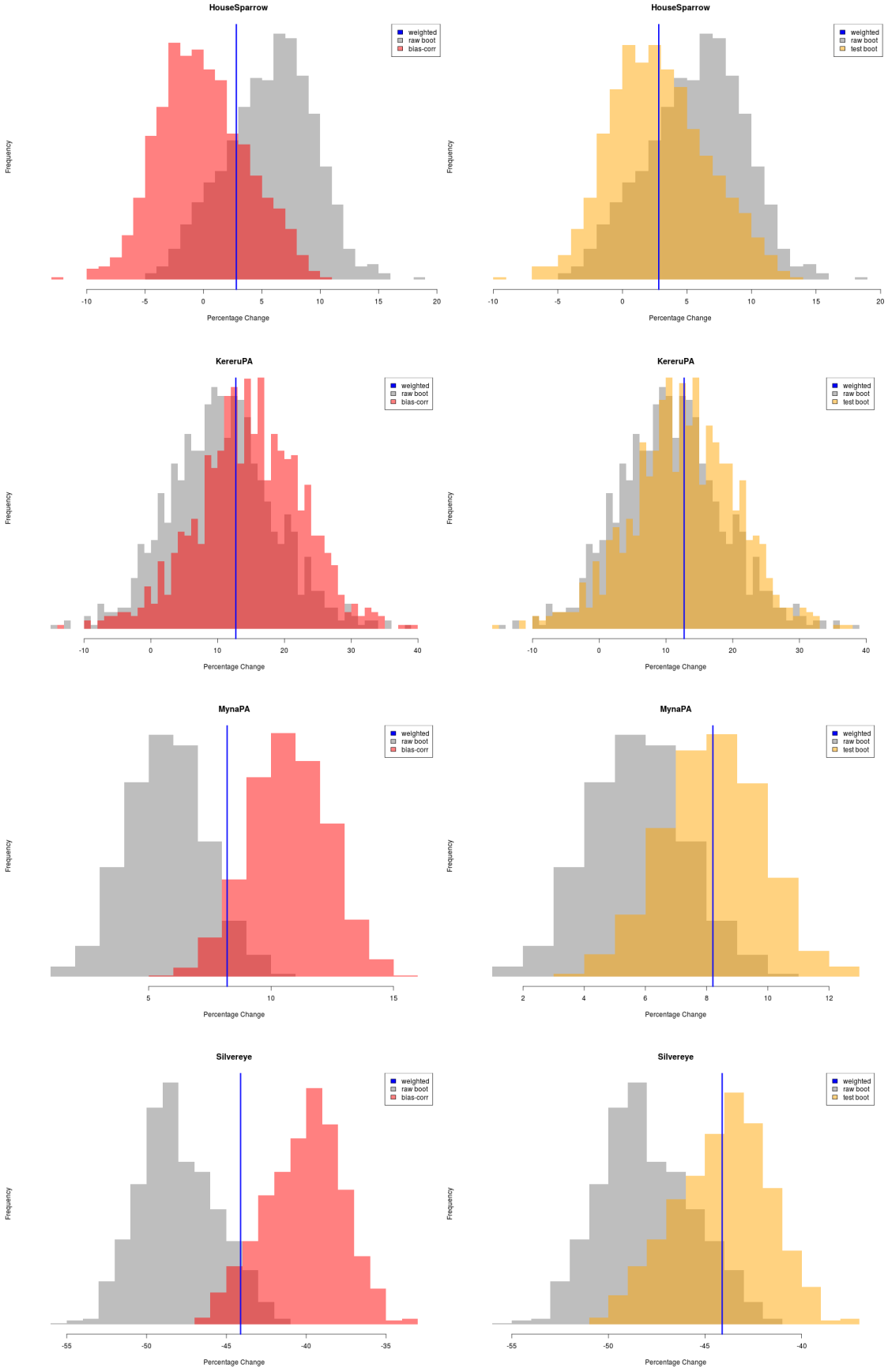


Figure 6 (continued)

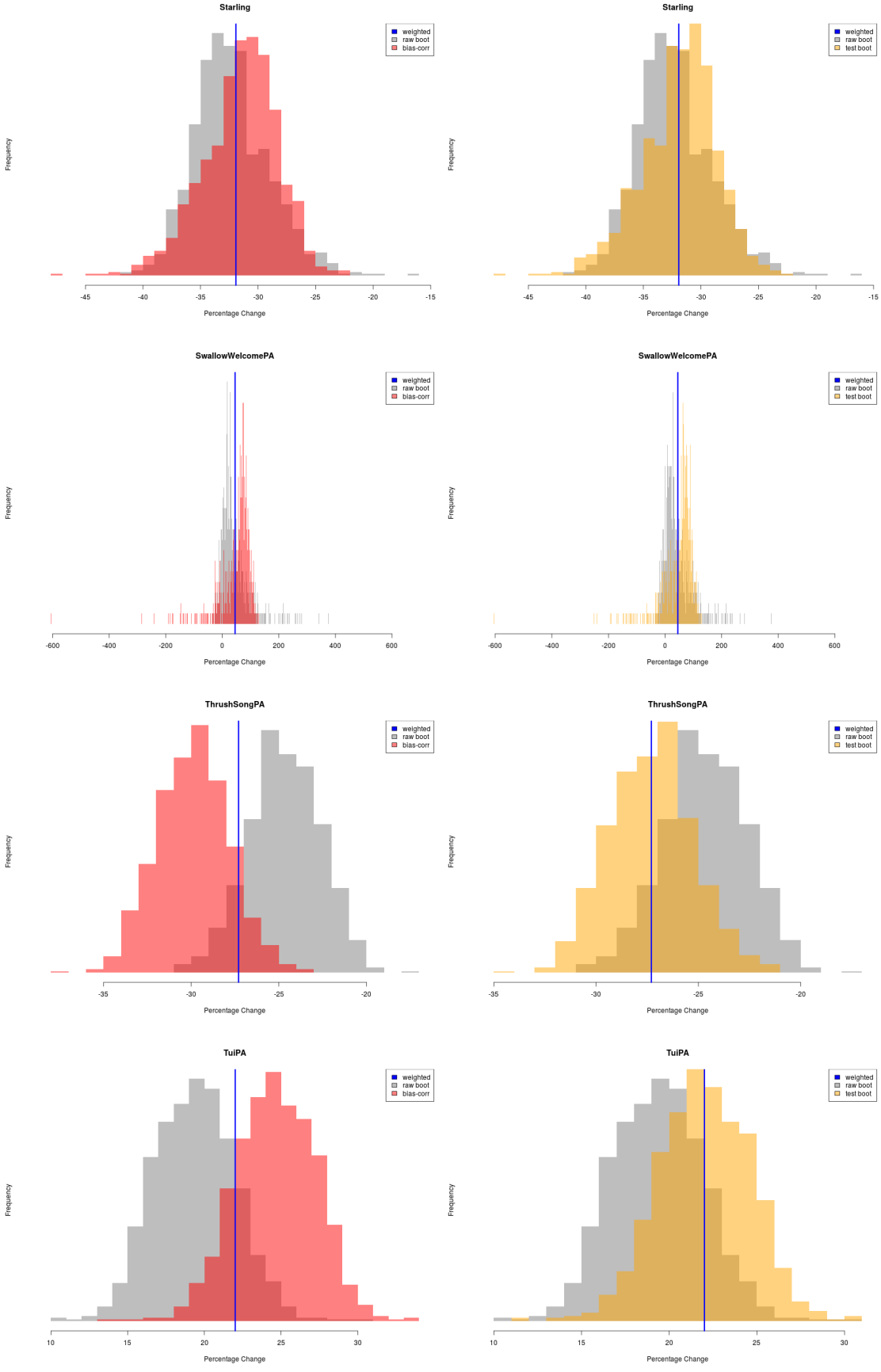


Figure 6 (continued)

5 Trends of concern or interest

To understand the significance of the New Zealand garden bird trends from a management perspective, we considered the trend estimates (and their respective confidence intervals) in relation to some alert thresholds. These alert thresholds are based on the system used by the British Trust for Ornithology[11] to draw attention to emerging population declines that may be of conservation concern.

Their system seeks to identify rapid declines (>50%) and moderate declines (>25% but <50%), with declines being measured at different time scales depending on the data available (ideally the most recent 25-, 10- or 5-year periods; Baillie & Rehfisch 2006). These thresholds are consistent across species. By exploring trends over different time periods, their aim is to place greater conservation emphasis on the long-term trends, but to use the short-term changes to identify trends that are continuing (or accelerating) from those that have ceased or reversed.

It is important to note that the British Trust for Ornithology trend alerts are only advisory and do not supersede the agreed, longer-term UK conservation listings (Eaton et al. 2015), which provide a more comprehensive assessment of the conservation status of each species (e.g. taking into consideration the species' population size and distribution).

Here we outline a standardised protocol used to classify the median weighted-bootstrap estimates of percentage change in bird counts and their respective confidence intervals (derived from the previous section of this report) to identify trends of concern or interest. The protocol classifies the trend direction (increasing, decreasing or no change) and size (no or little change, shallow, moderate or rapid). It then evaluates the strength of evidence available to support the trend assessment (ranked from insufficient or very weak to very strong). This evidence classification takes into consideration the percentage of bootstrap estimates that meet the trend threshold criteria and/or overlap zero. Species with lower variance and greater sample sizes will have stronger evidence.

5.1 Identifying and evaluating evidence for trend direction

For the study period, the trend was classified as declining or increasing when >50% of the bootstrap estimates of percentage change in bird counts met the following criteria respectively: $\Delta y_{si} < 0$ and $\Delta y_{si} > 0$. Trends that did not meet these criteria were classified as 'no change'. The strength of evidence to support those classifications was then evaluated using the standardised criteria (Table 6), taking into consideration the distribution of the bootstrap estimates and whether they overlapped zero or not.

For the 2007–2017 NZ Garden Bird Survey national data set, for example, we classified eight of the 14 species as declining and the remainder as increasing at the national scale (Table 7). For all but two species there was very strong evidence to support those trend classifications. For the remaining two species (bellbird and house sparrow), the 10–90% quantile range for

[11] http://www.bto.org/about-birds/birdtrends/2014/methods/alert-system

the bootstrap estimates included zero, so the strength of evidence for their respective trend classifications was rated as very weak. Broadly, the strength of evidence for trend direction was stronger at the national scale than at finer spatial scales.

Table 6. Classifying the strength of evidence to support any identified declining or increasing trends

Strength of evidence classification	***Classification criteria***	
	10–90% quantile range for the bootstrap estimates includes zero	*Percentage of bootstrap estimates meeting trend specification (decline: $\Delta y_{si} < 0$; increase: $\Delta y_{si} > 0$)*
Very strong	No	>90%
Strong	No	>80%
Moderate	No	>70%
Weak	Yes	>80%
	No	>60%
Very weak	Yes	>60% but ≤80%
	No	>50%

Table 7. Summary of bootstrap results and associated trend classification for 14 garden bird species at the national scale (based on NZGBS data for the period 2007–2017)

Species	***% bootstrap estimates***		***Bootstrap estimates include zero***	***Trend classification***	
	Decline	*Increase*		*Trend type*	*Strength of evidence*
Silvereye	100	0	0	Decline	Very strong
Chaffinch	100	0	0	Decline	Very strong
Goldfinch	100	0	0	Decline	Very strong
Blackbird	100	0	0	Decline	Very strong
Song thrush	100	0	0	Decline	Very strong
Starling	100	0	0	Decline	Very strong
Dunnock	99	0	0	Decline	Very strong
Bellbird	52	47	1	Decline	Very weak
House sparrow	23	76	1	Increase	Very weak
Kererū	5	94	0	Increase	Very strong
Fantail	0	99	0	Increase	Very strong
Greenfinch	0	99	0	Increase	Very strong
Tūī	0	100	0	Increase	Very strong
Myna	0	100	0	Increase	Very strong

5.2 Classifying trend size and strength of evidence

Having identified whether a species was declining or increasing, we then evaluated the level of change in bird counts to identify trends of concern or interest. Trends for the specified period of time and spatial scale were classified by comparing the median percentage change in bird counts to a range of threshold values (Table 8). We then evaluated the evidence to support these trend classifications (Table 9), taking into consideration the percentage of bootstrap estimates that breach the respective upper thresholds for declining trend size classes and the lower threshold for increasing trend sizes (Table 8).

Table 10, for example, summarises the NZGBS national trend classification for the period 2007–2017. Bird counts have declined moderately for four species (silvereye, starling, goldfinch and song thrush), undergone a shallow decline for three (chaffinch, dunnock and blackbird), changed little or not at all for four (myna, fantail, bellbird and house sparrow), and undergone a shallow increase for three (kererū, tūī and greenfinch). For seven species (silvereye, starling, chaffinch, bellbird, house sparrow, tūī and greenfinch), the evidence for the trend size categorisation was very strong. For the remaining species the strength of evidence ranged from very weak (dunnock, blackbird) to strong (myna, song thrush).

Table 8. Criteria used to classify long-term population trends for New Zealand's garden birds based on the median bootstrap estimates of percentage change in bird counts

Trend size classification	***Threshold range***		***Threshold colour***
	Lower limit	*Upper limit*	
Rapid decline	≥ –∞	≤ –50%	Red
Moderate decline	> –50%	≤ –25%	Amber
Shallow decline	> –25%	≤ –10%	Light amber
Little or no change	> –10%	≤ +10%	Light green
Shallow increase	> +10%	≤ +50%	Dark green
Moderate increase	> +50%	≤ +100%	Light blue
Rapid increase	> +101%	≤ +∞	Dark blue

Table 9. Classifying the strength of evidence to support the long-term trend classifications for New Zealand garden birds, where the threshold criteria for little or no change was > –10% but ≤ +10%, for declining trend sizes was less than or equal to the respective upper threshold (see Table 8), and for increasing trend sizes was greater than the lower threshold for each size class (see Table 8)

Strength of evidence classification	***Percentage of bootstrap estimates that meet the specified threshold criteria***
Very strong	≥90%
Strong	≥80%
Moderate	≥70%
Weak	≥60%
Very weak	≥50%
Insufficient	<50%

Table 10. Classification of trends and associated trend alerts for 14 garden bird species (based on NZGBS data for the period 2007–2017)

		Quantile estimates		% bootstrap estimates meet alert threshold criteria							Trend classification			
				Decline				Increase			Direction		Size	
Species	Median	10%	90%	Rapid	Moderate	Shallow	No or little change	Shallow	Moderate	Rapid	Trend	Evidence	Trend	Evidence
Greenfinch	47	29	61	0	0	0	0	99	39	0	Increase	Very strong	Shallow	Very strong
Tūī	22	18	25	0	0	0	0	100	0	0	Increase	Very strong	Shallow	Very strong
Kererū	12	2	22	0	0	0	35	64	0	0	Increase	Very strong	Shallow	Weak
Myna	8	6	10	0	0	0	86	13	0	0	Increase	Very strong	Little or no change	Strong
Fantail	8	5	11	0	0	0	73	26	0	0	Increase	Very strong	Little or no change	Moderate
House sparrow	2	–1	8	0	0	0	96	3	0	0	Increase	Very weak	Little or no change	Very strong
Bellbird	0	–4	3	0	0	0	99	0	0	0	Decline	Very weak	Little or no change	Very strong
Blackbird	–10	–13	–7	0	0	59	40	0	0	0	Decline	Very strong	Shallow	Very weak
Dunnock	–11	–17	–5	0	0	59	40	0	0	0	Decline	Very strong	Shallow	Very weak
Chaffinch	–16	–19	–12	0	0	99	0	0	0	0	Decline	Very strong	Shallow	Very strong
Goldfinch	–26	–32	–22	0	71	100	0	0	0	0	Decline	Very strong	Moderate	Moderate
Song thrush	–27	–29	–24	0	87	100	0	0	0	0	Decline	Very strong	Moderate	Strong
Starling	–31	–36	–28	0	99	100	0	0	0	0	Decline	Very strong	Moderate	Very strong
Silvereye	–43	–47	–41	0	100	100	0	0	0	0	Decline	Very strong	Moderate	Very strong

6 Data visualisation

We developed standardised protocols for generating summary graphics and reports for *State of NZ Garden Birds* results following several years of stakeholder consultation.[12] These new protocols are set up so that new data and results can readily be added in future years in a cost-effective manner. They are designed to:

- remove barriers to local-scale information that stakeholders have indicated they are interested in (e.g. local councils and community groups)
- produce graphics that can be used as a standalone resource, can be readily communicated to the interested public, and can help build the NZGBS profile using:
  - trend classification categories and associated colour coding to help the user readily interpret and identify changes in bird counts of interest
  - species icons to help people recognise the species of interest to them but at the same time educate those who are not familiar with the species
  - NZGBS branding (logo and colours) to help build awareness and recognition of our resources (Rodríguez Estrada et al. 2016; Wanrooy et al. 2016)
- reduce the transaction costs of producing and updating the high-resolution graphics suitable for publishing online or in print, while ensuring the process of generating them is transparent and readily repeatable (this is achieved by ensuring the R-code, graphics and data resources used to generate the bar plots are fully documented and readily accessible via the MWLR DataStore).[2]

The *State of NZ Garden Birds 2017* resources are publicly available on the DataStore, allowing the user to view, download or embed the resources. The resources are published as three data sets: summary and technical reports (34 PDF files); bar plots by location (192 images; PNG; ZIP); and species bar plots and maps (28 images; PNG; ZIP).

6.1 Maps

The species maps are designed as simple, eye-catching graphics that can be used as standalone resources (Figure 7; MacLeod et al. 2018b). They provide a high-level summary of the national and regional results. Templates are available to produce the maps in English and te reo Māori (although the latter still require formal review and approval by a certified translator).

- The title poses a simple question to make the reader think about the information the graphic aims to communicate.
- The subtitle gives the spatial scale and time period.

[12] Graphics were progressively improved over a 4-year period in response to feedback from stakeholders, who had a diverse range of backgrounds, roles and responsibilities in bird monitoring and reporting in New Zealand This feedback was facilitated through a series of focus groups, workshops and online surveys carried out as part of the MBIE-funded project on Building Trustworthy Biodiversity Indicators.

- Common, Māori and Latin names for the species are displayed, with different emphasis on the various names depending on the template.
- The species icon is displayed to help people recognise or identify the bird if they are not familiar with it. The icon's background and caption are colour coded to communicate the national results.
- The map shows how the trend categories vary across the regions, with a simple scale explaining the colouring coding used.
- The MWLR and NZGBS logos are displayed in the lower left and lower right corners (respectively) to acknowledge the source of the resource.
- A brief text statement (perpendicular to the graphic) explains the sample size (i.e. the number of garden surveys) used to derive the graphic.

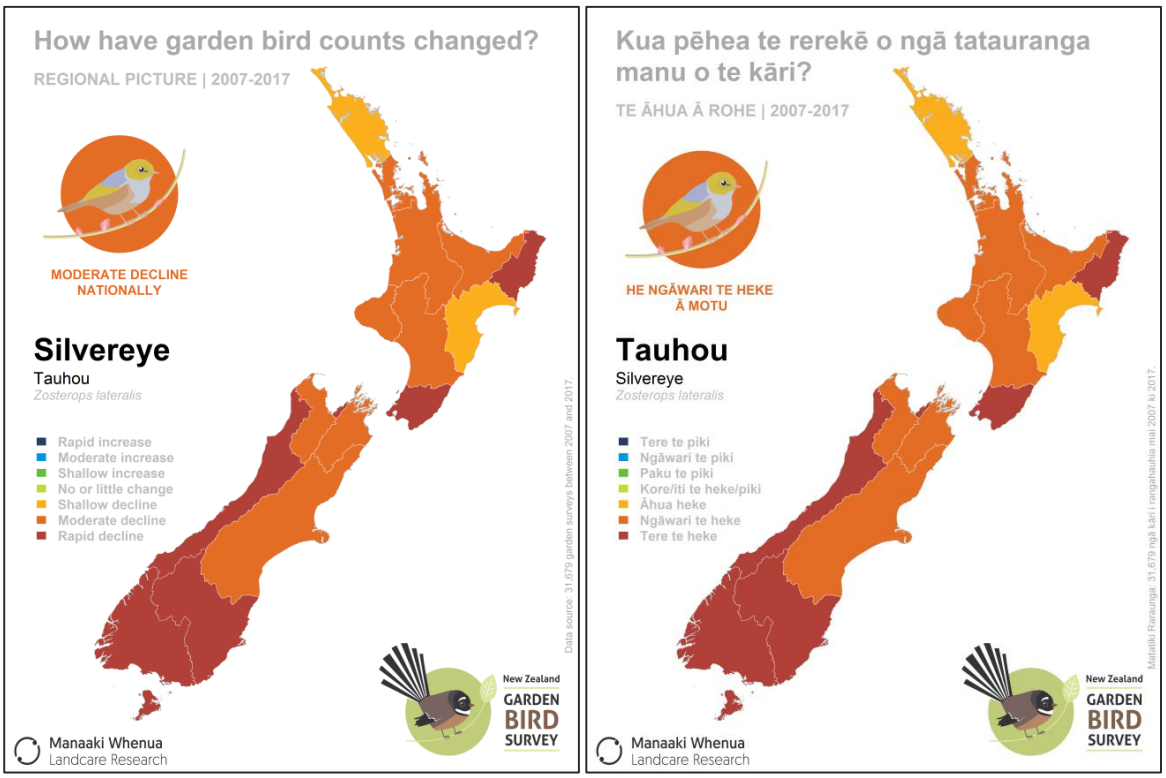


Figure 7. Example of species maps summarising the national and regional results in English and te reo Māori.

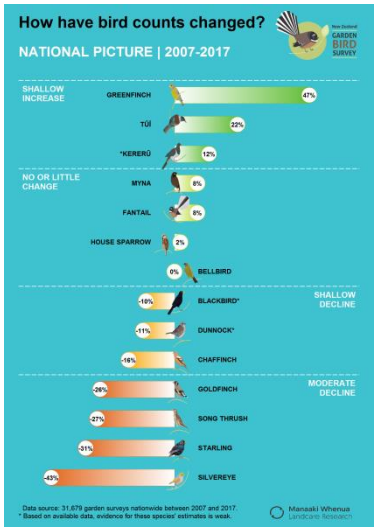
6.2 Bar plots

A standardised template is used to generate bar plot graphics at the national, regional and local scales, with a te reo Māori translation also available for the national scale (Figure 8; MacLeod 2018). A similar template is available to produce bar plots for individual species at the regional scale (Figure 8). This can be readily adapted in the future to produce similar plots for local scales.

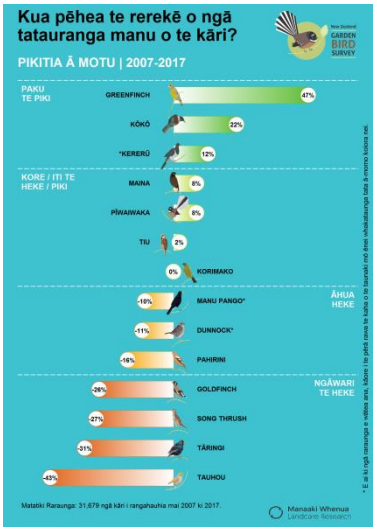
These bar plots are designed to provide a bit more detail than the maps while still being simple, eye-catching graphics. They are also designed to be used as standalone resources. Each bar plot is a composite plot generated using R-code.

- The title poses a simple question to make the reader think about the information the graphic aims to communicate.
- The subtitle gives the spatial scale and time period.
- Common and Māori names for the species are displayed in the English and te reo plots, respectively. The species icon is also displayed alongside the species name to help people recognise or identify the bird if they are not familiar with it.
- The length of each bar is proportional to the median percentage change in bird counts, with the metric also displayed explicitly at the end of each bar. Each bar is colour coded to reflect the species' trend-alert categories (matching those shown in the species maps described above), and horizontal lines and labels are used to group the species according to their respective trend-alert categories. Asterisks highlight results where the evidence available for the trend category is weak.
- A brief text statement (below or perpendicular to the graphic) provides the sample size (i.e. the number of garden surveys) used to derive the graphic. It also explains what the asterisks signify (i.e. those species where the available evidence is weak).
- The NZGBS and MWLR logos are displayed in the upper and lower right corners, respectively, to acknowledge the source of the resource.
- The background colour of each plot meets the NZGBS brand specifications.

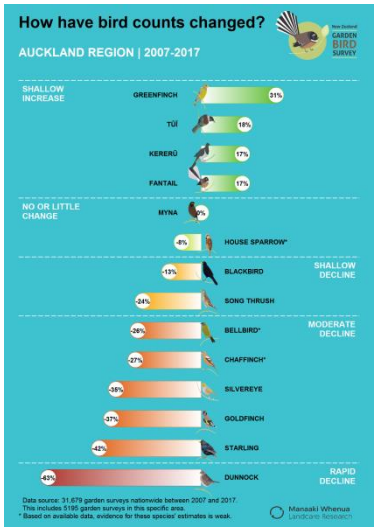
A. National bar plot (English)



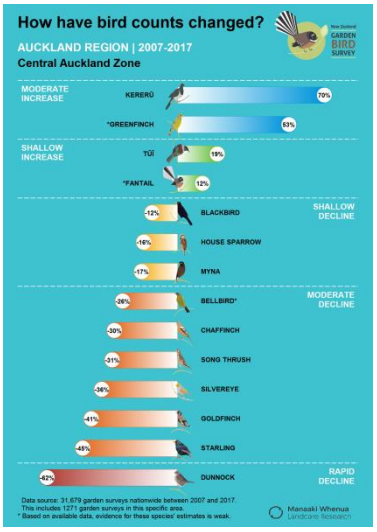
B. National bar plot (te reo)



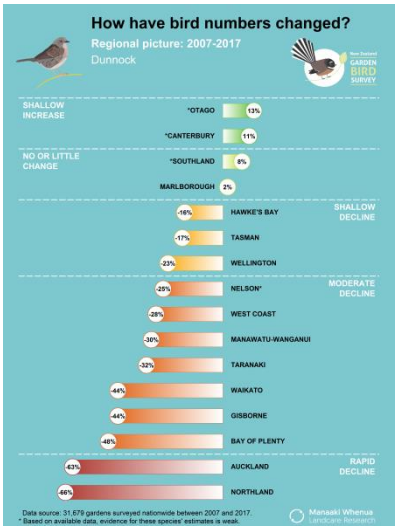
C. Regional bar plot



D. Urban area bar plot



E. Introduced species across regions



F. Native species across regions

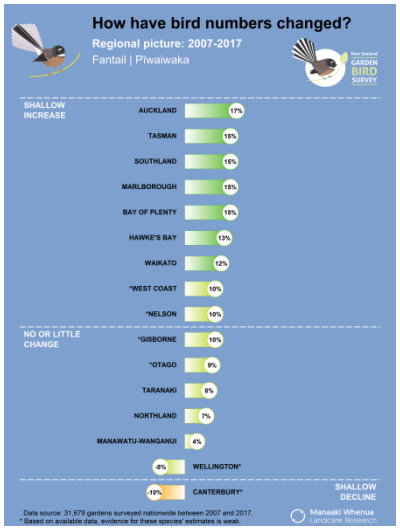


Figure 8. Example bar plot outputs for different spatial scales, and for introduced and native species across regions.

6.3 Dot plots

A standardised template is used to generate dot plot graphics at the national, regional and local scales (Figure 9). These dot plots aim to provide a summary of the detailed statistical metrics while still making it relatively easy for the reader to review a large volume of information quickly. Each dot plot is a composite plot generated using R-code.

- The title poses a simple question to make the reader think about the information the graphic aims to communicate.
- The subtitle gives the spatial scale and time period.
- The main plot displays:
    - common and, where appropriate, Māori names for each species in the far left and right columns, respectively
    - median changes in bird counts
    - 80% confidence intervals for the 1,001 bootstrap replicates
    - a colour-coded dot plot showing the change class for each species, based on the 1,001 bootstrap replicates, as indicated by a double circle; the degree of shading indicates where these replicates lie
    - a grey-scale dot plot showing the quality rating category for each species (i.e. the strength of evidence for the change class based on the 1,001 replicates; quality was rated on a six-point scale from insufficient to very strong, as indicated by 0 to 5 grey-shaded dots).
- The NZGBS logo is displayed in the upper right corner to acknowledge the source of the resource.

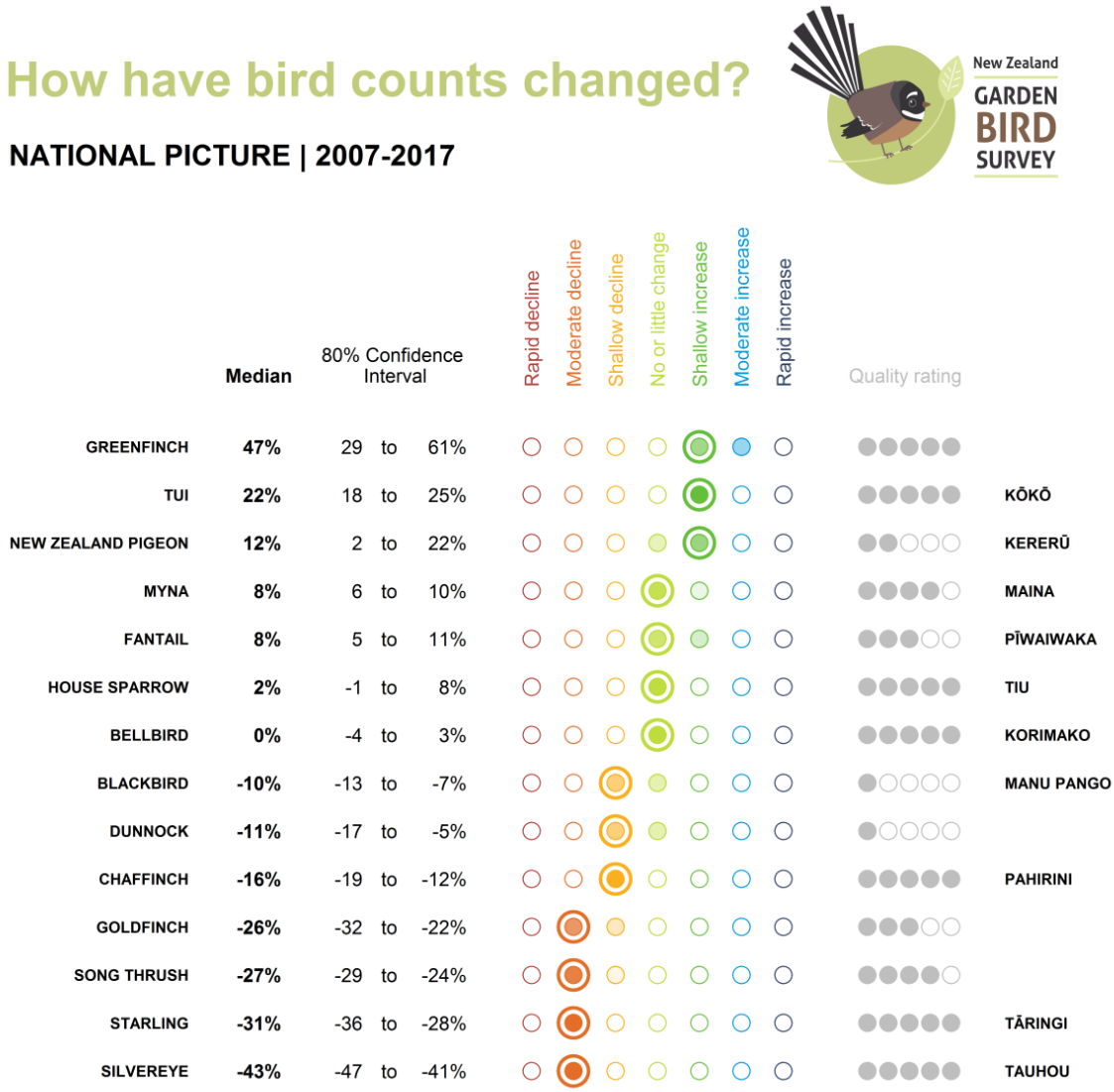


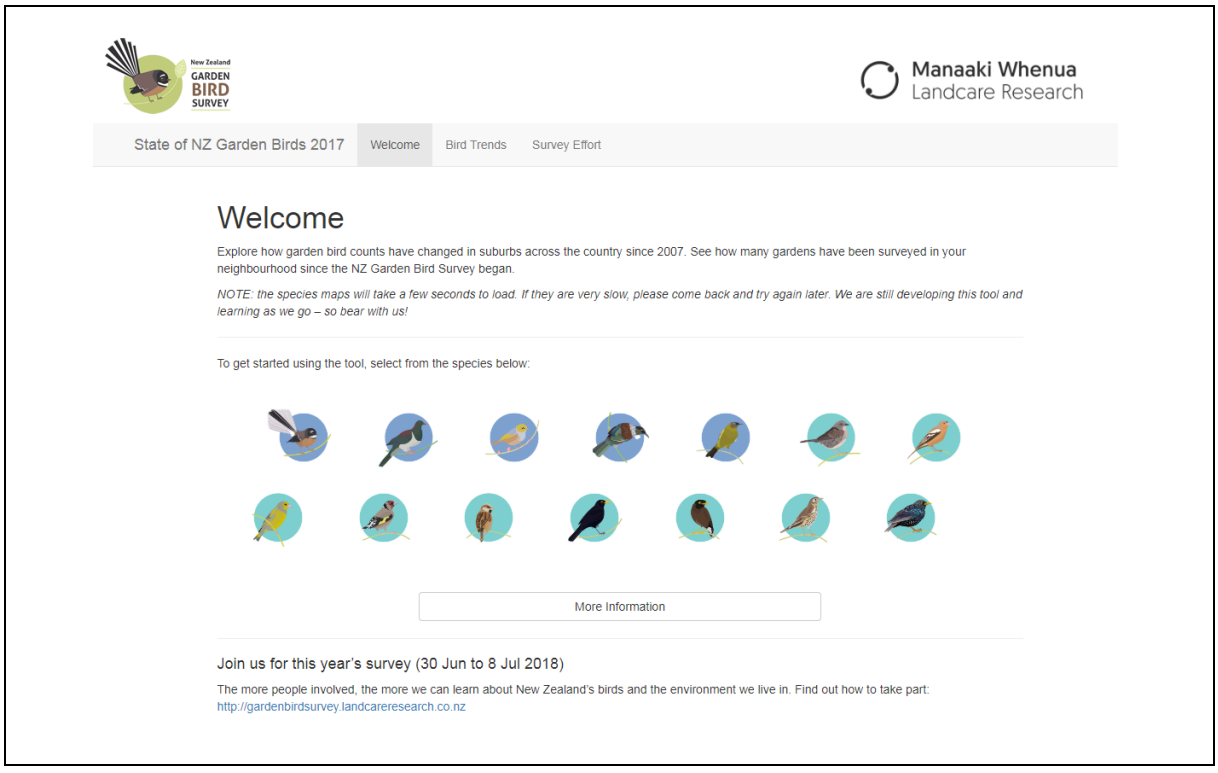
Figure 9. Sample dot plot for 14 species showing their median change in counts, 80% confidence intervals for the 1,001 bootstrap replicates, as well as their change class (double circles) and bootstrap distribution in relation to the trend classes (where the shading is proportional to the distribution of bootstrap replicates among the change classes) and quality rating (ranging from weak to very strong, as indicated by 0 to 5 grey-shaded dots).

6.4 Interactive data

Using the Shiny[13] package in R, we developed an interactive application that allows the user to explore the NZGBS results for each species at a range of spatial scales (MacLeod, Green et al. 2018). Information is available for each region, town/city or neighbourhood (as defined by the Statistics NZ region, urban area and area unit spatial layers). The NZGBS logo and MWLR logo are clearly displayed in the application header to acknowledge the source of this information. The application consists of three tabs.

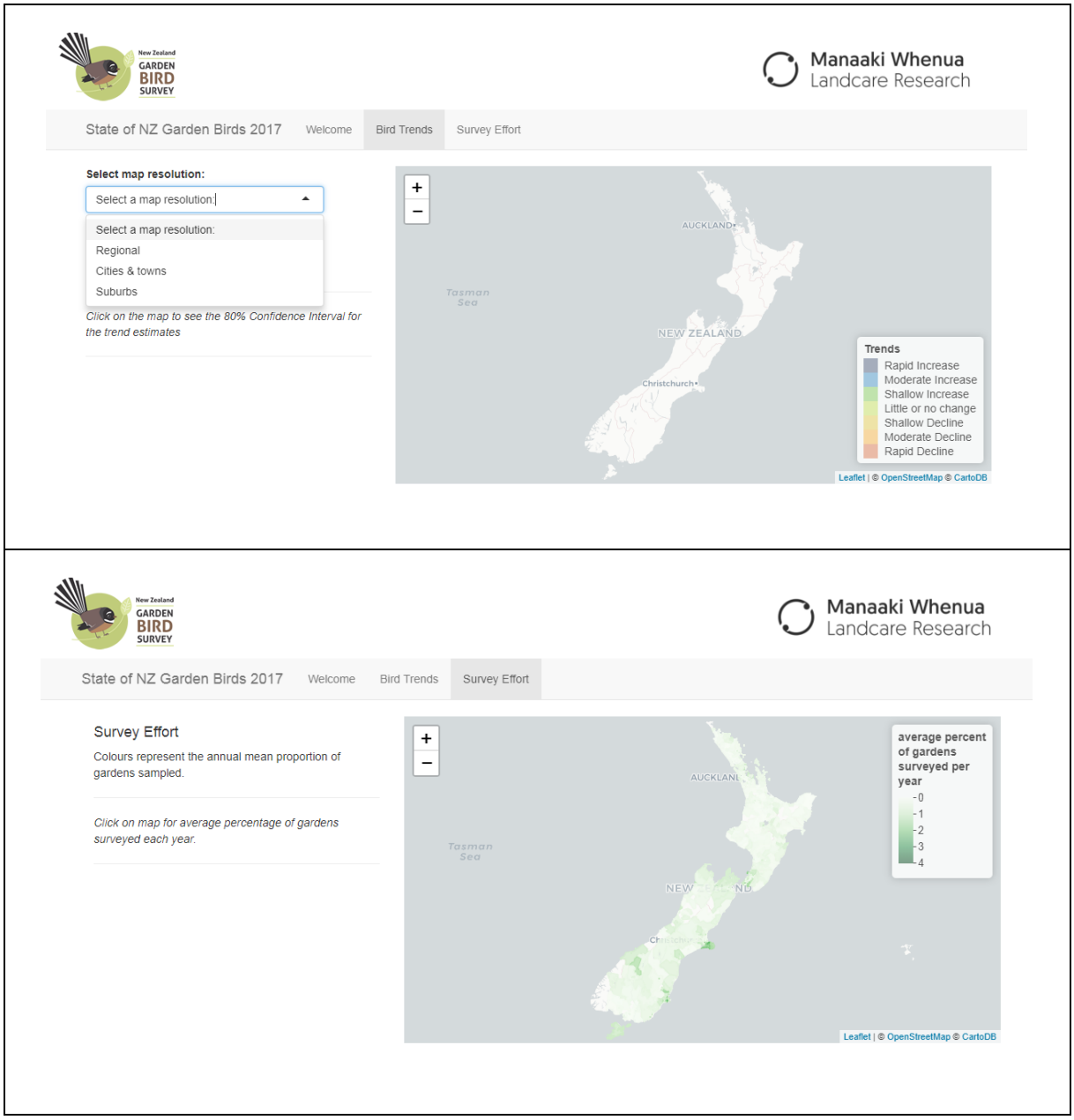
- *Welcome:* an introduction to the application and the NZGBS. The user can initiate the application by clicking on one of the species icons or on the tab menu (Box 1). The users can learn more about the application by clicking the 'More information' button.
- *Bird trends:* the user selects the species, spatial scale and location of interest using a series of dropdown menus. The results are displayed on a 'leaflet' map (Box 2). The user can adjust the map using the zoom buttons.
- *Survey effort:* the user can explore each neighbourhood (Statistics NZ area unit) to find out how many garden surveys were completed in that area for the period 2007 to 2017 (Box 2). These results are also displayed on a 'leaflet' map.

Box 1. Screenshot of the 'Welcome' tab for the interactive application showing the results of *State of NZ Garden Birds 2017*



[13] https://shiny.rstudio.com/

Box 2. Screenshot of the 'Bird Trends' and 'Survey Effort' tabs for the interactive application showing the results of *State of NZ Garden Birds 2017*



6.5 Summary reports

National and regional summary reports were generated as PDF files using the knitr function in R.

National summary reports

The national reports combine the existing national bar plot and species map graphics with some new graphics (using the knitr function in R) to produce the PDF files (Box 3). [14]

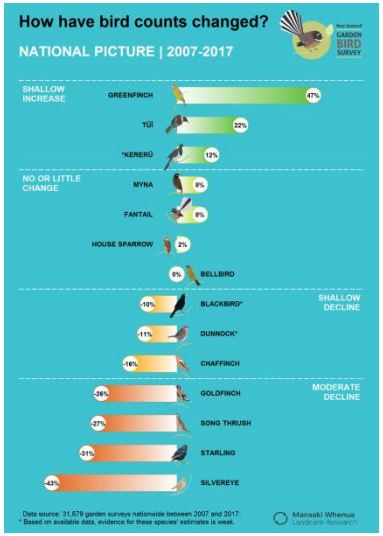
- *Front cover:* the title page (produced by the MWLR graphics team) includes the NZGBS and MWLR logos to acknowledge the source of the information.
- *Backyard beats:* background on the report, and the headline results.
- *National summary:* a bar plot[15] showing the median changes in bird counts for the period of interest.
- *Thank you:* acknowledging the volunteer effort and showing the number of garden surveys per year.
- *Methods:* a brief explanation of the goal of the report and the analytical approach, as well as the criteria used to draw attention to trends of concern or interest.
- *Species maps:* for each of the 14 species, showing the high-level summary of national and regional results.[16] Each page of these maps displays the NZGBS and MWLR logos to acknowledge the source of the information.
- *Back cover:* provides the citation for the report, along with the NZGBS and MWLR logos to acknowledge the source of the information. It also advertises the upcoming 2018 NZGBS campaign.

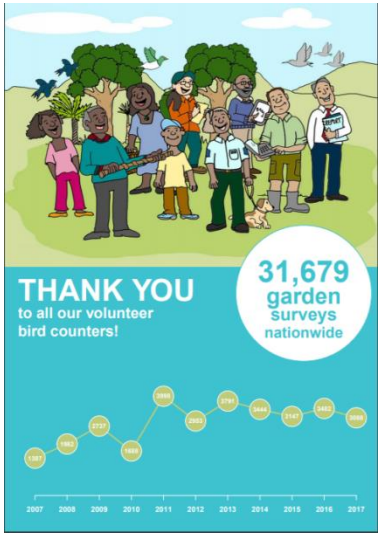
[14] The PDF files generated from R were very large and so had to be manually optimised using the Acrobat software.

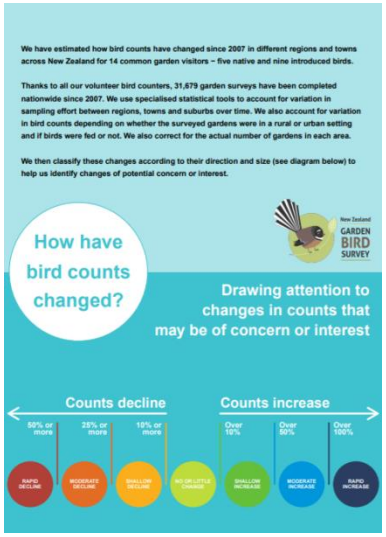
[15] Existing bar plot images were imported here (MacLeod et al. 2018a).

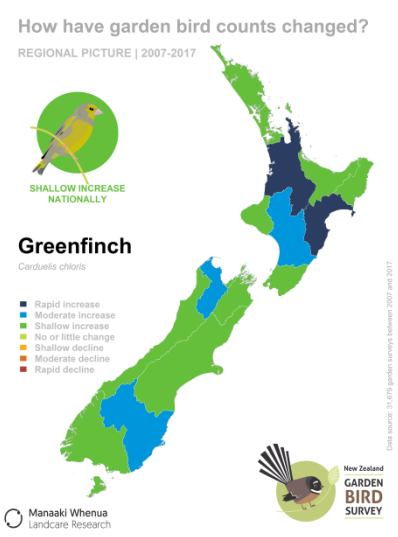
[16] Existing species map images were imported here (MacLeod et al. 2018b).

Box 3. National summary report sample pages: front cover, headlines, national bar plot, thank you, introduction, regional maps and back cover









Regional summary reports

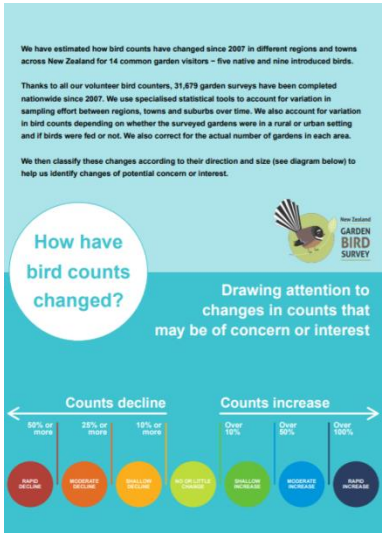
The regional reports also combine the existing bar plot graphics with some new graphics (using the knitr function in R) to produce the PDF files (Box 4).[17]

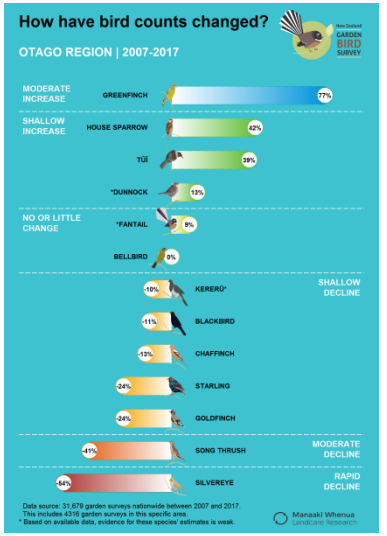
- *Front cover:* Titles and map highlighting the region of interest, a graph showing the number of garden surveys available for each year in that region, and the NZGBS and MWLR logos to acknowledge the source of the information.[18]
- *Introduction:* Provides a brief explanation of the goal of the report and the analytical approach, as well as the criteria used to draw attention to trends of concern or interest.
- *Regional summary:* Bar plots[15] showing the median changes in bird counts for the region and period of interest.
- *Urban area summaries:* Two pages are displayed for each urban area within the region (as defined by Statistics NZ). The first page displays the titles and map highlighting the urban area of interest with a graph showing the number of garden surveys available for each year for that urban area. The second page shows the bar plot[15] summary for the urban region. Each page of these summaries displays the NZGBS and MWLR logos to acknowledge the source of the information.
- *Back cover:* Provides the citation for the report along with the NZGBS and MWLR logos to acknowledge the source of the information. [18] It also advertises the upcoming 2018 NZGBS campaign.

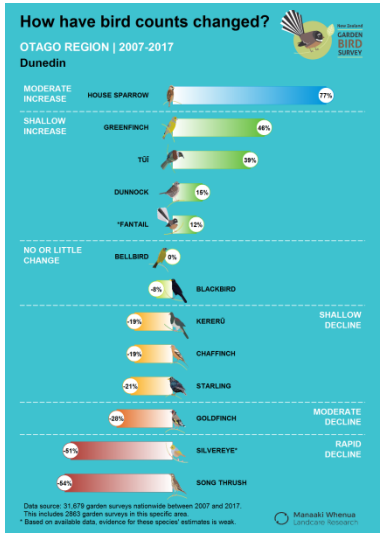
[17] The PDF files generated from R were very large and so had to be manually optimised using the Acrobat software.

[18] These front and back cover images were generated as separate images in R and then imported because the PDF function does not recognise the unicodes for macrons.

Box 4. Regional summary report sample pages: front cover, introduction, regional bar plot summary, urban area pages, and back cover







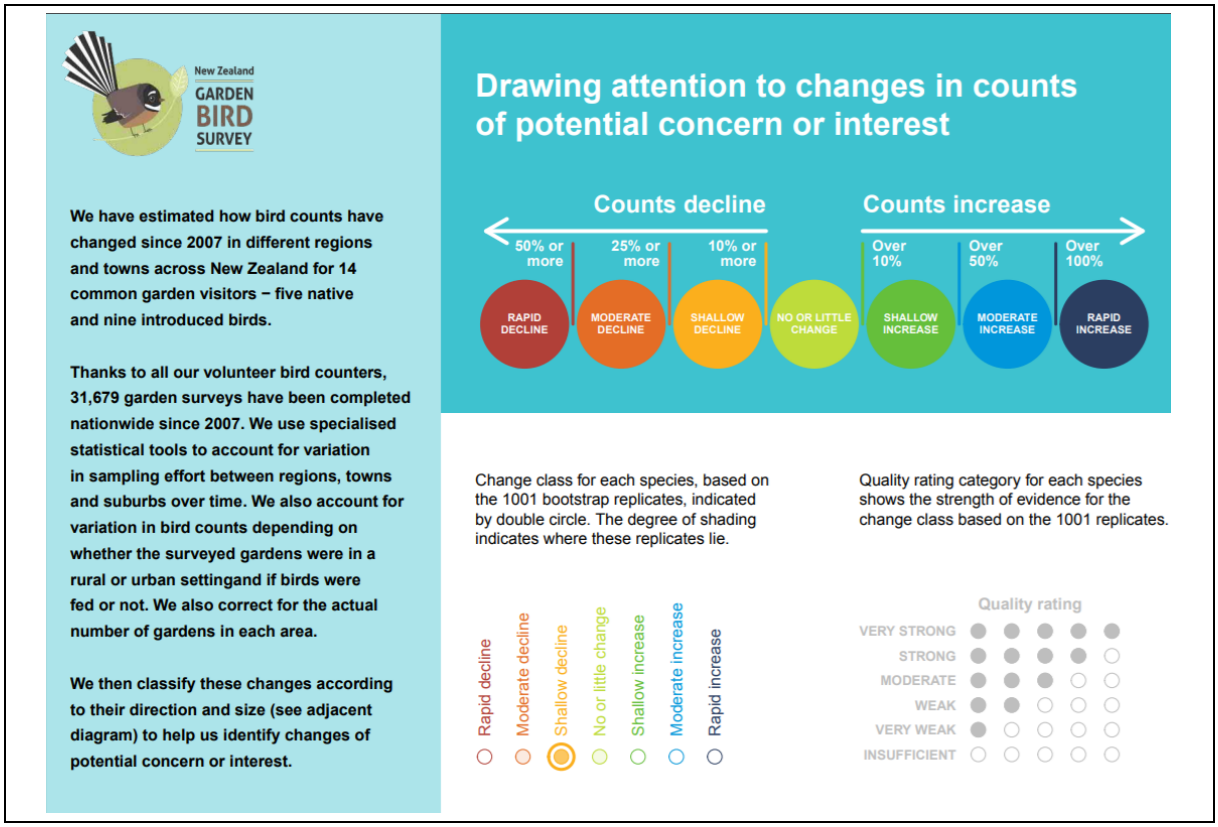
6.6 Technical reports

The national and regional technical reports were designed primarily with a professional audience (e.g. biodiversity managers in councils or community groups) in mind – they assume some basic understanding of statistics. They are generated as PDF files using the knitr function in R, combining dot plot graphics (prepared separately) with some new graphics (Box 5 to Box 7).[18]

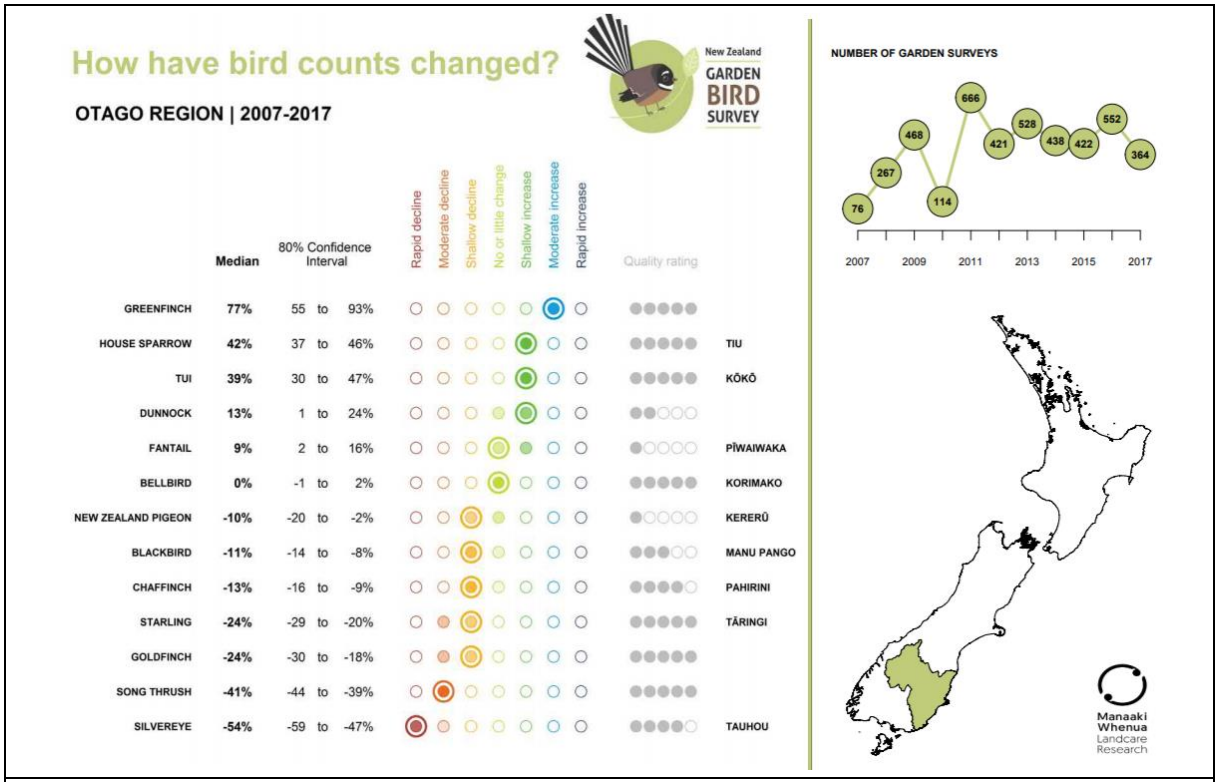
- *Front cover:* titles and map highlighting the region of interest, and the NZGBS and MWLR logos to acknowledge the source of the information (Box 5).[19]
- *Introduction:* provides a brief explanation of the goal of the report and the analytical approach, as well as the criteria used to draw attention to trends of concern or interest (Box 6).
- *Statistical summary:* a one-page summary provided for national, regional and urban areas, as appropriate (Box 7). These are composite plots showing: (1) the median changes in bird counts with the 80% confidence interval for the 1,001 bootstrap replicates: these are printed alongside a colour-coded dot plot showing the distribution of the bootstrap replicates in relation to the trend classification categories as well as a quality rating (i.e. our evidence evaluation, ranging from insufficient/weak to very strong); (2) a plot showing the number of garden surveys available for each year; and (3) a map showing the location of the area being considered.
- *Back cover:* provides the citation form for the report along with the NZGBS and MWLR logos to acknowledge the source of the information (Box 5).[19] It also advertises the upcoming 2018 NZGBS campaign.

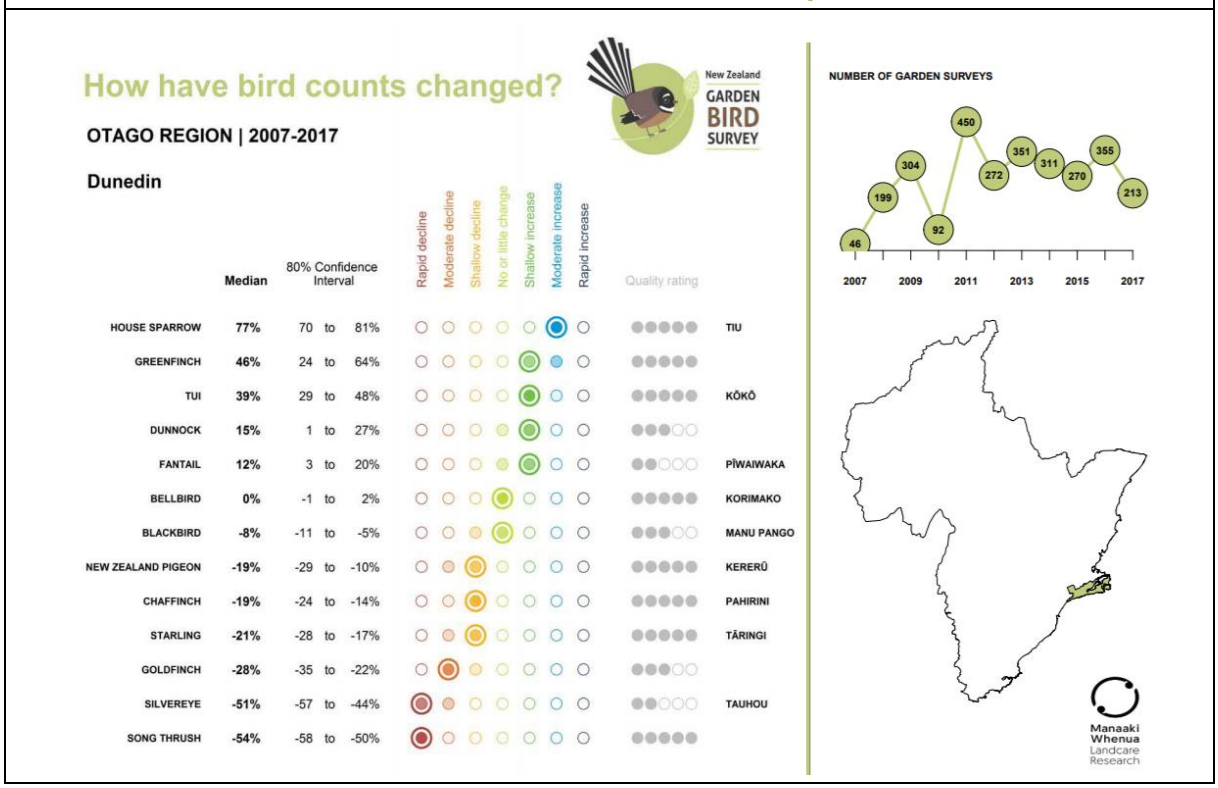
Box 5. Technical report: front and back cover sample pages

Box 6. Technical report: overview of our analytical approach and standardised criteria used to interpret the results



Box 7. Technical report: sample statistical summaries for a regional and an urban area





7 Communication strategy

The resources developed to support the *State of NZ Garden Birds* were published on the NZGBS web page, along with an online article published on the MWLR web page to advertise them. Initially this online article was advertised via a media release and social media channels (Facebook and Twitter). This was then followed up with a series of focused posts highlighting the diversity of resources available. We also advertised the report to previous NZGBS participants via an email. Here we describe this communication strategy in more detail and evaluate its impact.

7.1 Web page

The home page for the *State of NZ Garden Birds 2017* displays a gallery of thumbnails and subtext to provide the user with an overview of the different resources available (Box 8). Nine of the 10 thumbnails were produced using a standardised template in R; the header and logo format was consistent for all thumbnails, with the underlying graphics reflecting the basic traits of the resources on the associated sub-page. The resources were placed in order of technical difficulty, with the higher level and simpler graphics presented at the top of the page and the more detailed statistical information and methods toward the bottom of the page. Supporting text was provided on each page to introduce the resources, recognising that people visiting the page may not have seen the home page or other resources available on it.

The *State of NZ Garden Birds 2017* web pages were viewed over 10,000 times between 19 June and 9 July 2018 (Table 11), a five-fold increase on the previous year (about 2,100 views for the 2016 report web pages). The home page for the report was the most visited page, with over 5,700 views and 4,400 unique views. The national headlines, summary reports and regional bar plots were the most popular sub-pages with over 848 views each. The pages for the summary and technical reports and methods (behind the scenes) had the highest levels of engagement in terms of the amount of time spent on the page, although this may in part reflect the time taken to load the PDF reports.

Engagement metrics for the Shiny app allowing people to explore garden bird trends in different neighbourhoods were accessed by almost 400 new users, who visited the page around 550 times, more than double the previous year (Table 12). Each user spent less than a minute interacting with the resource. Most users accessed the resource using a desktop computer (80%), and tablets (12%) were used more frequently than mobile phones (9%) for viewing. Engagement rates were lower than we achieved with our interactive *New Zealand Garden Bird Atlas*, which we launched in 2016 (Table 12).

Box 8. Layout of web page for *State of NZ Garden Birds 2017*

GARDEN BIRD SURVEY

- Doing the survey
- Enter your data
- Progress update
- Colouring Competition
- State of NZ Garden Birds 2017
  - National picture
  - Regional graphs
  - Who is involved?
  - Reports | Summary
  - Species graphs
  - Species maps
  - Reports | Technical
  - Interactive maps
  - Calculating changes in bird counts
- State of NZ Garden Birds 2016
- Why take part
- Feathered fun
- Get social
- Resources for schools
- The story so far
- Discover and learn
- Behind the scenes

Home » Our Science » Plants, animals & fungi » Animals » Birds » Garden bird survey » State of NZ Garden Birds 2017

STATE OF NZ GARDEN BIRDS 2017 - TE ĀHUA O NGĀ MANU O TE KĀRI I AOTEAROA

Birds act as 'backyard barometers' - telling us about the health of the environment we live in. We should be listening.

Birds are signalling significant changes in our environment over the last 11 years, according to the *State of NZ Garden Birds 2017 | Te Āhua o ngā Manu o te Kāri i Aotearoa 2017* report just released by Manaaki Whenua – Landcare Research.

Using cutting-edge techniques, researchers have distilled a large information base – bird counts gathered by New Zealanders from over 31,000 garden surveys since 2007 – into simple but powerful metrics.

Explore these resources to learn more about your favourite garden birds and places.

Download State of NZ Garden Birds

Backyard beats | What are our birds telling us?

Explore how bird counts have changed across your region

Great team effort | Thank you to all our supporters over the years!

How counts changed in urban and rural areas in your region

Graphs | Changes in species counts across regions

Maps | Changes in species counts across regions

Statistical summaries for urban and rural areas in each region

Explore how bird counts have changed in your neighbourhood

Behind the scenes | Calculating changes in bird counts

Table 11. Web pages for *State of NZ Garden Birds 2017*, with view and engagement metrics (downloaded from Google analytics for the period 1 June to 9 July 2018)

Page	*Page views*	*Unique page views*	*Avg. time on page (sec)*
Report home page[19]	5,723	4,392	73
National headlines[20]	1,004	856	105
Summary reports[21]	984	684	189
Regional bar plots[22]	848	745	117
Species maps[23]	437	389	110
Technical reports[24]	411	253	130
Species bar plots[25]	333	296	118
Interactive application[26]	166	107	59
Who is involved?[27]	138	130	46
Behind the scenes[28]	118	104	127

Table 12. Shiny apps for State of Garden Birds 2017, cf. NZ Garden Bird Atlas (2007–2015), with view and engagement metrics (source: Google analytics on 14 Nov 2018)

Engagement metrics	*Shiny app*				
	State of Garden Birds 2017		NZ Garden Bird Atlas (2007–2015)		
	2017	*2018*	*2016*	*2017*	*2018*
New users	145	396	510	161	126
Page visits	197	551	1428	257	174
Average session (seconds)	40	54	104	75	53

[19] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017

[20] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/national-headlines

[21] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/reports-summary

[22] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/regions

[23] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/species-maps

[24] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/reports-technical

[25] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/regional-species

[26] https://landcare.shinyapps.io/GBS_Explorer/

[27] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/involved

[28] https://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys/state-of-nz-garden-birds-2017/behind-scenes

7.2 Media outlets

A short article summarising the key findings of *State of NZ Garden Birds 2017* was prepared for our collaborating organisations (Birds NZ, Forest and Bird, Topflite) to publish in their own articles and magazines, along with our national bar plot.

The article was subsequently adapted for an online story[29] published by MWLR. This version included the national bar plot graphic and two species maps (silvereye and tūī) as well as links to the report on the NZGBS webpage and associated resources on the MWLR online DataStore.

A media release about the *State of NZ Garden Birds 2017* was published online on 19 June 2018. There was strong uptake by media outlets, with five magazine articles, around 43 newspaper articles, and about five radio and two television items. The total audience reach of these articles was over 3.1 million, with good national and regional coverage.

About 61% of news items adopted the 'backyard barometer' concept and around 20% used the bar plot graphics we provided. Another 14% included an adaptation of our graphics results. A quarter of the articles included the regionally or locally relevant NZGBS metrics.

7.3 Facebook

Nine Facebook posts publicising *State of NZ Garden Birds 2017* were published in June 2018: five on the MWLR Facebook page (Table 13) and four on the NZGBS Facebook page (Table 14). In total, these posts reached 61,600 people and appeared 94,600 times on newsfeeds, with engagement levels of 1,700 (around 85% of this activity occurred on the MWLR page).

- The first post on each page linked to a short note summarising the findings of the report, with links to the relevant web pages; this reached over 12,000 people in total.
- A post displaying the regional bar plots as a gallery reached the highest number of people (over 33,000); this post was only published on the MWLR page and was boosted[30] by 40%.
- The species maps, also posted as a gallery, achieved the highest levels of engagement (i.e. the total number of reactions, comments or shares relative to the number of people reached; MWLR: 4.6%; NZGBS: 14.5%), at least double that of the other posts considered here.
- The NZGBS Facebook posts generally had lower reach than the MWLR posts but achieved higher levels of engagement.

[29] https://www.landcareresearch.co.nz/about/news/snippets/garden-birds-are-signalling-changes-in-our-enviro

[30] The user pays for their post to actively boosted or promoted to target audiences on Facebook.

Table 13. Posts on the MWLR Facebook page relating to the *State of NZ Garden Birds 2017* and the reach, impressions and engagement for each post. [31]

Date	*Type*	*Post text*	*Reach*	*Impressions*	*Engagement*	*Shares*	*Ratio*
19 June	Note[32]	Garden birds are signalling changes in our environment	9,300	14,100	220	61	2.3%
21 June	Link to TVNZ[33]	Watch: the 31,000 surveys carried out by the NZ public since 2007 as part of the New Zealand Garden Bird Survey show significant changes in the bird populations of several species in New Zealand, both native and introduced. The more people who participate in the survey, the clearer the picture for NZ will become. This year's survey runs from 30th June - 8th July; full details on the Manaaki Whenua - Landcare Research website: www.landcareresearch.co.nz/gardenbird. Make your count count!	4,800	6,600	143	31	2.9%
23 June	Spatial bar plots[34]	State of NZ's Garden Birds 2017 - check out changes in species counts in your region since the New Zealand Garden Bird Survey started in 2007. This year's survey starts next Saturday; sharpen your pencil and get ready to add your data to the picture. www.landcareresearch.co.nz/gardenbird	33,400[35]	55,000	675	148	2.0%
23 June	Species maps[36]	These maps show changes in bird counts across New Zealand since the NZ Garden Bird Survey, NZ's longest-running citizen science project, began in 2007. What's going on where you live? If you have an hour between 30th June & 8th July, why not take part in this year's survey and help us build a clearer picture of changes across the nation. www.landcareresearch.co.nz/gardenbird	2,400	3,400	110	37	4.6%
24 June	Species bar plots[37]	Here's another way of looking at the bird count data coming out of the New Zealand Garden Bird Survey. See how different species has fared in different regions. This year's survey starts on Saturday - are you ready? www.landcareresearch.co.nz/gardenbird. One hour between 30th June - 8th July is all that is needed to contribute to NZ's longest-running citizen science project.	2,400	2,900	52	6	2.2%

[31] Reach is the number of unique Facebook members that view the post. Impressions is the number of times a post appears on a Facebook newsfeed (the same post can appear on an individual member's newsfeed multiple times). Engagement is the total number of reactions, comments or shares.

[32] https://www.facebook.com/notes/manaaki-whenua-landcare-research/garden-birds-are-signalling-changes-in-our-environment/10156264278017534/

[33] https://www.facebook.com/landcareresearch/posts/10156268468647534

[34] https://www.facebook.com/landcareresearch/posts/10156273753412534

[35] Boosting for this post cost c. $100, equivalent to c. 40% of the post reach.

[36] https://www.facebook.com/landcareresearch/posts/10156273687587534

[37] https://www.facebook.com/landcareresearch/posts/10156276402767534

Table 14. Posts on the NZGBS Facebook page relating to the State of NZ Garden Birds 2017 report.

Date	*Type*	*Post text*	*Reach*	*Impressions*	*Engagement*	*Shares*	*Ratio*
19 June	Note[38]	Birds act as "backyard barometers", telling us about the health of the environment we live in – and we should be listening. There is cautiously positive news for tūī – and possibly kererū - but silvereye has declined by 43% nationally since the survey started in 2007, and six of the most common introduced species are also in decline. The 'State of NZ Garden Birds 2017 | Te Āhua o ngā Manu o te Kāri I Aotearoa 2017' was released today. This report details changes observed since the NZ Garden Bird Survey started in 2007, with over 31,000 bird counts gathered by volunteers.	2,800	3,200	163	30	6%
21 June	Link to TVNZ[39]	Watch: the 31,000 surveys carried out by the NZ public since 2007 as part of the New Zealand Garden Bird Survey show significant changes in the bird populations of several species in New Zealand, both native and introduced. The more people who participate in the survey, the clearer the picture for NZ will become. This year's survey runs from 30th June - 8th July; details will of course be posted on this page, with activities and additional resources on the Manaaki Whenua - Landcare Research website: www.landcareresearch.co.nz/gardenbird. Make your count count!	1,200	1,700	52	11	4.3%
23 June	Species maps[40]	These maps show changes in bird populations across New Zealand since the NZ Garden Bird Survey began in 2007. What's going on where you live? If you have an hour between 30th June & 8th July, why not take part in this year's survey and help us build a clearer picture of changes across the nation. www.landcareresearch.co.nz/gardenbird	829	1,200	120	62	14.5%
24 June	Species bar plots[41]	Here's another way of looking at the bird count data coming out of the New Zealand Garden Bird Survey. See how different species has fared in different regions. This year's survey starts on Saturday - are you ready? www.landcareresearch.co.nz/gardenbird. One hour between 30th June - 8th July is all that is needed to contribute to NZ's longest-running citizen science project.	4,500	6,500	135	38	3%

[38] https://www.facebook.com/nzgbs/posts/884496351746544

[39] https://www.facebook.com/nzgbs/posts/886289968233849

[40] https://www.facebook.com/nzgbs/posts/888595858003260

[41] https://www.facebook.com/nzgbs/posts/889703787892467

7.4 Twitter

Only two posts were published on the MWLR Twitter account publicising *State of NZ Garden Birds 2017* (Table 15). One linked to an article about the report – this was retweeted 15 times and liked 38 times. The other advertised a link to a television video clip, which was retweeted four times and liked three times.

Table 15. MWLR Twitter posts relating to *State of NZ Garden Birds 2017*

Date	*Type*	*Post text*	*Retweets*	*Likes*	*Comments*
18 June	Link to article[42]	Birds act as "backyard barometers", telling us about the health of the environment we live in – and we should be listening.	15	38	1
20 June	Link to TVNZ[43]	Watch: the 31,000 surveys carried out by the NZ public since 2007 as part of the New Zealand Garden Bird Survey show significant changes in the bird populations of several species in New Zealand, both native and introduced.	4	3	

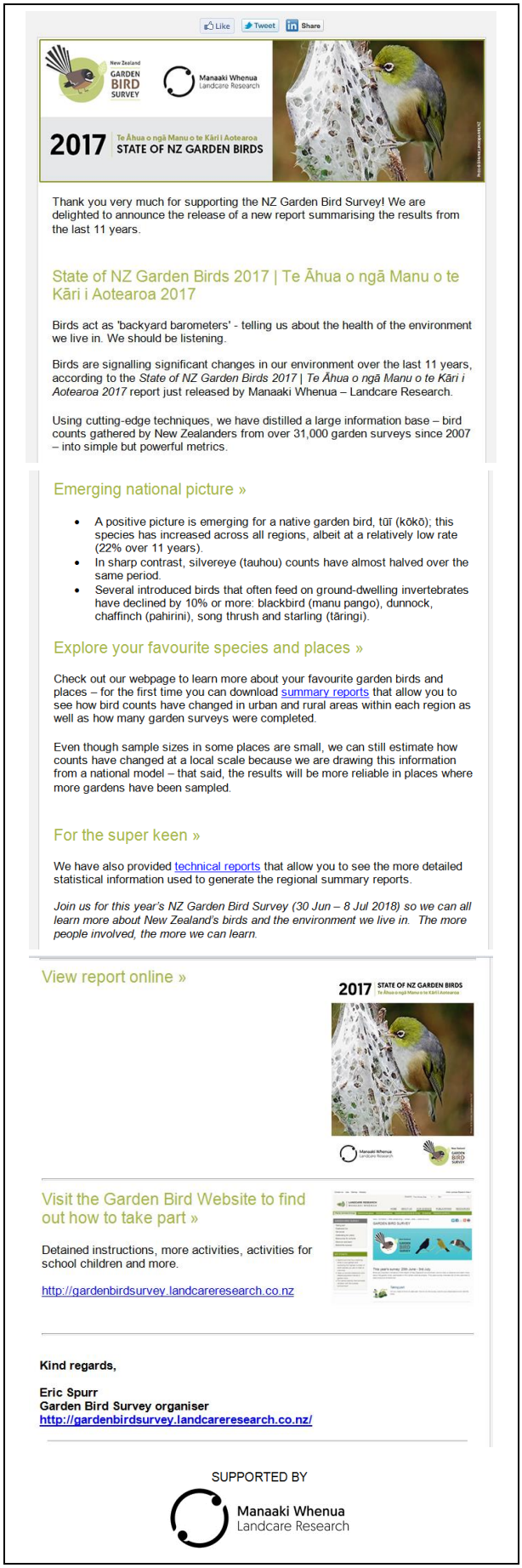
7.5 Email

An email (Box 9) announcing the publication of the *State of NZ Garden Birds* was sent on 21 June 2018 to 8,680 people on the NZGBS mailing list (via the Vertical Response platform). About 45% of those emails were opened and c. 25% of recipients clicked through to at least one of our online resources. Approximately 12% of the emails bounced and 0.3% unsubscribed.

[42] https://twitter.com/LCR_NZ/status/1008894750173417478

[43] https://twitter.com/LCR_NZ/status/1009566900668588038

Box 9. Email sent to 8,680 people on the NZGBS mailing list (via Vertical Response)



Like Tweet Share

New Zealand GARDEN BIRD SURVEY

Manaaki Whenua Landcare Research

2017 Te Āhua o ngā Manu o te Kāri i Aotearoa
STATE OF NZ GARDEN BIRDS

Thank you very much for supporting the NZ Garden Bird Survey! We are delighted to announce the release of a new report summarising the results from the last 11 years.

State of NZ Garden Birds 2017 | Te Āhua o ngā Manu o te Kāri i Aotearoa 2017

Birds act as 'backyard barometers' - telling us about the health of the environment we live in. We should be listening.

Birds are signalling significant changes in our environment over the last 11 years, according to the *State of NZ Garden Birds 2017 | Te Āhua o ngā Manu o te Kāri i Aotearoa 2017* report just released by Manaaki Whenua – Landcare Research.

Using cutting-edge techniques, we have distilled a large information base – bird counts gathered by New Zealanders from over 31,000 garden surveys since 2007 – into simple but powerful metrics.

Emerging national picture »

- A positive picture is emerging for a native garden bird, tūī (kōkō); this species has increased across all regions, albeit at a relatively low rate (22% over 11 years).
- In sharp contrast, silvereye (tauhou) counts have almost halved over the same period.
- Several introduced birds that often feed on ground-dwelling invertebrates have declined by 10% or more: blackbird (manu pango), dunnock, chaffinch (pahirini), song thrush and starling (tāringi).

Explore your favourite species and places »

Check out our webpage to learn more about your favourite garden birds and places – for the first time you can download summary reports that allow you to see how bird counts have changed in urban and rural areas within each region as well as how many garden surveys were completed.

Even though sample sizes in some places are small, we can still estimate how counts have changed at a local scale because we are drawing this information from a national model – that said, the results will be more reliable in places where more gardens have been sampled.

For the super keen »

We have also provided technical reports that allow you to see the more detailed statistical information used to generate the regional summary reports.

Join us for this year's NZ Garden Bird Survey (30 Jun – 8 Jul 2018) so we can all learn more about New Zealand's birds and the environment we live in. The more people involved, the more we can learn.

View report online »

Visit the Garden Bird Website to find out how to take part »

Detained instructions, more activities, activities for school children and more.

http://gardenbirdsurvey.landcareresearch.co.nz

Kind regards,

Eric Spurr
Garden Bird Survey organiser
http://gardenbirdsurvey.landcareresearch.co.nz/

SUPPORTED BY

Manaaki Whenua
Landcare Research

8 Public awareness and interest in resources

After entering their data online, NZGBS 2018 participants were invited to take part in a feedback survey to help us improve their experience.

8.1 Feedback survey

This survey included two questions specifically relating to *State of NZ Garden Birds 2017* . The first question asked if they were aware of the report. Then, if the response was positive, they were asked if they were aware of the various resources associated with the report and if they liked them. There was also an open comments box where people could provide additional feedback.

The response rate was high, with 4,213 people (about 80% of NZGBS 2018 participants who entered their data online) answering the first question alone. The number of people responding to the questions about specific resources ranged from 1,737 to 1,911 people.

For comparison, we also present the results for the same survey carried out in 2017 for *State of NZ Garden Birds 2016*.

8.2 Awareness and interest in resources

The percentage of respondents aware of our *State of NZ Garden Birds* reports increased from 45% in 2017 (n = 2381) to 49% in 2018 (n = 4213). For those respondents who were aware of the report, most (70–80%) were aware of and interested in the species maps, regional and species graphs, and regional reports (note: the latter only available in 2018; Table 16). Over 50% were aware of and interested in the interactive maps (on the Shiny app) and the technical reports (only released in 2018).

Open box comments relating to these resources were provided by 223 people. About 20 people said they were unaware of some resources that we listed. Another 29 indicated that they had heard about the report via television, radio or newspaper but had not looked at our online resources specifically; some indicated that they intended to do so.

Specific concerns raised about the content or presentation of our resources included:

- issues loading or using the interactive maps (three comments)
- difficulty reading the headers on the graph thumbnails on the webpage before enlarging them (one comment)
- graphics were hard to read because the reader was colour blind (one comment)
- disappointed that the technical reports did not give any of the methods used or the statistical analysis of the data or the error/variance of the data (one comment).

With respect to the last point, although our technical reports did not provide a detailed breakdown of the analytical approach (such as is provided in this report), they give an overview of our methods and provide 90% confidence intervals and median estimates for the percentage changes in counts.

Table 16. Awareness of and interest in the range of *NZ State of Garden Birds* report resources developed in 2017 and 2018

Resources		*Response percent*				*Response count*				
		Aware of it but not looked at it	*Looked at it, but not really interested*	*Looked at it and very interested*	*Looked at it and loved it*	*Aware of it but not looked at it*	*Looked at it, but not really interested*	*Looked at it and very interested*	*Looked at it and loved it*	*Total*
Species maps	2017	16%	4%	66%	14%	168	36	682	142	1,028
	2018	18%	2%	64%	17%	337	32	1,222	320	1,911
Regional and species graphs	2017	18%	3%	64%	14%	185	32	646	141	1,004
	2018	21%	3%	60%	17%	381	47	1,106	318	1,852
Interactive maps for exploring your suburb	2017	40%	6%	42%	12%	386	60	404	115	965
	2018	44%	7%	36%	14%	766	121	623	241	1,751
Regional summary reports	2018	27%	3%	55%	15%	504	62	1,001	267	1,834
Regional technical reports	2018	43%	9%	37%	11%	749	164	641	183	1,737

A number of participants conveyed a strong interest in our report, with some indicating how the results also spurred them on to participate in the NZGBS and encourage others to do the same (Box 10).

Box 10. Selection of positive 'open box' comments relating to *State of NZ Garden Birds 2018*

> *"Thank you. Citizen science at its best"*
>
> *"Really great report, easy to read, understand and share"*
>
> *"The report was what prompted me to take part, our region was really underrepresented in the survey, so myself and other members of the Bluff Hill Motupohue Environment Trust decided we needed to participate :)"*
>
> *"It is fantastic to see the data providing such a comprehensive picture. I'd love to know if people are getting better at identifying our native birds. And I'm worried about tauhou, but wonder if that is displacement back into the bush by tui and more people feeding birds."*
>
> *"I was surprised how few survey results come in for some regions near me, so asked for a flyer to distribute at work. Better advertising needed?"*
>
> *"Just really happy to contribute to citizen science data collecting. Best wishes!"*
>
> *"I found the report format very user friendly, it made data easy to find and interpret."*
>
> *"Really interesting, it is great that Landcare Research are using their initiative to get NZers [to] take part and then use raw data to produce useful comparative reports. Great work! Well done! Citizen science and the boffins working together! I love it!"*

9 Discussion, conclusions and next steps

9.1 Building infrastructure to secure data legacy

We have demonstrated how an online DataStore can be used to document, manage and store the wide range of resources required for, and generated by, the preparation and publication of the *State of NZ Garden Birds 2017*. This infrastructure holds significant potential to further reduce the transaction costs of producing the report, sharing related resources, and evaluating the performance of the NZGBS, its governance and communication strategies.

The inability to store data sets using a hierarchical framework is one limitation of the online DataStore design. This is especially the case when there is a large volume of resources stored in a collection, as it is not possible to use the search function for finding unpublished data sets. As a compromise, we used the "Group" function within the online DataStore to direct users to key subsets of data (e.g. Graphics, Live or Archived files).

One of the challenges with setting up this infrastructure was trying to anticipate the breadth of users and their ability to search for and access the range of available resources, and setting up the resources accordingly. When loading the core NZGBS graphics, for example, this required taking into consideration the needs of a wide range of users including community groups, schools and other professionals. In contrast, the data editing, analysis and visualisation protocols are more specifically aimed at a professional audience with experience using R.

While very detailed protocols explaining the R-code may be useful for less experienced users and for communicating the complexity of our data editing, analysis and visualisation protocols, an overview of the protocol with links to the relevant R-code, input and output files is a more cost-effective option for documenting our processes.

9.2 Telling a richer story to reach a wider audience

By telling a richer story with the *State of NZ Garden Birds 2017*, we successfully reached a more diverse and larger audience while increasing engagement. Complex techniques distilled 31,000 bird counts (gathered by volunteers nationwide since 2007) into simple but powerful metrics for multiple species and spatial scales.

We have demonstrated how standardised criteria can be used to help user interpretation – both in terms of the level of change in bird counts and the strength of evidence available to support that change classification. We have also shown how standardised code can be used to generate visually appealing graphics that can be readily understood by a non-specialist audience and communicated via a wide range of channels.

Although te reo translations of some resources had been completed, these were not published because they required review by a professional translator and the team lacked the capability to write supporting social media posts in te reo to publicise these resources.

By building a stronger brand for the NZGBS and its resources, we are helping to build engagement with it.

9.3 Climbing the social engagement ladder to increase participation

Our communication strategy significantly increased awareness of and engagement with the report resources compared to previous years. This increase was evident on multiple communication channels, with high activity levels on the report web pages, high uptake by national and local media outlets (which also adopted our 'backyard barometer' concept, and 30% used our bar plot graphics to report the results), high levels of reach and newsfeed appearances on social media, and interaction statistics for email advertisements sent to previous participants.

Our resources were actively shared on social media by individuals, community groups, NGOs and government agencies (including local and central departments), often using them to encourage others to take part in the NZGBS 2018. Local predator-free groups were especially visible this year promoting our resources. More NZGBS participants were also aware of our report resources and shared their enthusiasm for them. They also signalled how having seen

the low levels of participation within their locality (based on our reports) inspired them and others to participate in the NZGBS 2018.

9.4 Recommended next steps

- *Data legacy:* edit, document and load the outstanding resources listed in Table 1.
- *Source and edited data:* establish governance strategy and protocols for sharing data.
- *Trend analysis and interpretation:* investigate issues flagged in relation to model fit and bootstrapping (in particular for the grey warbler and welcome swallow), and invite a panel review of the approach to finalise and establish current protocols as the standard; in the longer term, automatically link to the DataStore directly using APIs to access resources.
- *Data visualisation and communication* – capability is required to support the review and publication of te reo resources in future years: invite a stakeholder review of resources to determine whether further refinement of these resources is required to make them useful and relevant.
- *Communication strategy:* work more closely with stakeholders to build on the success of this year's strategy and educate them about the level of effort required to build engagement.

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