Manaaki Whenua
Landcare Research

NZ Garden Bird Survey 2018: data editing, analysis and interpretation methods

May 2019

New Zealand
GARDEN
BIRD
SURVEY

NZ Garden Bird Survey 2018: data editing, analysis and interpretation methods

Contract Report: LC3484

Catriona J. MacLeod, Simon Howard, Andrew M. Gormley, Eric B. Spurr

Manaaki Whenua – Landcare Research

Reviewed by:	*Approved for release by:*
Sarah Richardson	Gary Houliston
RPAL – Enhancing Biodiversity	Portfolio Leader – Enhancing Biodiversity
Manaaki Whenua – Landcare Research	Manaaki Whenua – Landcare Research

Contents

Summary

Purpose of this report

This report summarises the data editing, analysis and interpretation protocols for *State of NZ Garden Birds 2018 | Te Āhua o ngā Manu o te Kāri i Aotearoa*, which are as follows:

- editing the raw bird count data ready for analysis
- calculating changes in bird counts over the last 10-year and 5-year periods 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.

Source data

- Our analysis is based on annual NZ Garden Bird Survey (NZGBS) records gathered from gardens by volunteers nationwide the last 10-year period (2008–18: n = 34,686 records) and the last 5-year period (2013–18: n = 20,274 records).
- Records were classified in relation to three Statistics NZ 2018 spatial boundary layers[1] (region, territorial authority and urban rural).[2] 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.
- Between 0.11% and 0.28% of all New Zealand gardens were surveyed each year nationally; cumulative coverage of region, territorial authority and urban rural area units was ≥70%. Most records were gathered from regions or territorial authorities 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 and counts were converted into presence/absence records.

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).

---

[1] https://datafinder.stats.govt.nz/layer/92201-meshblock-higher-geographies-2018-high-definition/

[2] For definitions, see: http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/geographic-areas/pg4.aspx

- The percentage change in bird count estimates for two periods (2008–18 and 2013–18) for each of the weighted bootstrap runs was calculated for each species.
- Model performance was evaluated as follows.
  - A visual inspection was made of annual national point estimates derived from 10-year and 5-year models relative to weighted national median estimates. These estimates were broadly aligned for all but four species. For house sparrow, silvereye and starling, models accurately reflected underlying trends but point estimates were consistently low, signalling that future analyses need to identify other environmental covariates to produce more accurate point estimates. Model fit for grey warbler was poor, probably due to zero-inflated data.
  - A visual inspection was also made 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 trends equivalent to 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 over 10 years. It also flags species with little or no change in counts[3] (>10% decline but ≤10% increase over 10 years).
- 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. In broad terms, the strength of evidence for trend direction and size was stronger at the national scale than at finer spatial scales, and for the 10-year period than for the 5-year one.
- At the national scale over the last 10 years, bird counts have:
  - declined moderately for two species: silvereye and starling
  - undergone a shallow decline for three species: dunnock (*Prunella modularis*), goldfinch (*Carduelis carduelis*) and song thrush (*Turdus philomelos*)

[3] This includes presence/absence metrics.

  - changed little or not at all for five species: chaffinch (*Fringilla coelebs*), blackbird, house sparrow, myna (*Acridotheres tristis*), and bellbird (*Anthornis melanura*)
  - undergone a shallow increase for two species: fantail (*Rhipidura fuliginosa*) and tūī (*Prosthemadera novaeseelandiae*)
  - undergone a moderate increase for two species: kererū (*Hemiphaga novaeseelandiae*) and greenfinch (*Carduelis chloris*).
- Early warnings were signalled for 10 species, where their 5-year trends differed from the 10-year ones:
  - the rate of decline has slowed in the last 5 years for silvereye, starling and song thrush, but increased for goldfinch
  - there have been shallow increases for two species (blackbird and myna) that have undergone little or no change over the last 10 years
  - the rate of increase has slowed for greenfinch but accelerated for tūī and kererū.
- For the 10-year period, the evidence for the trend size categorisation was very strong for 10 species (silvereye, goldfinch, song thrush, blackbird, house sparrow, myna, bellbird and tūī); for the remaining four species the strength of evidence ranged from moderate (kererū and greenfinch) to strong (chaffinch and dunnock). For the 5-year period, evidence was strong or very strong for all species except silvereye and house sparrow, with moderate and weak classifications.

Discussion and conclusions

This report builds on earlier work exploring how recent advances in statistical modelling techniques could be used to cost-effectively calculate consistent and robust metrics at multiple spatial scales. Key improvements include:

- better accounting for:
  - variation in garden composition, bird-feeding activities and trends at four spatial scales, as well as uncertainties in trend estimates
  - spatial and temporal variation in sampling effort by weighting estimates according to the actual number of gardens within different neighbourhoods across the country
- reporting the percentage change in bird counts for any given period and spatial scale, as this metric is easier to communicate and for people to understand than the slope estimates derived from the models (the metrics previously considered)
- helping the user more readily understand and interpret the results – the percentage change estimates (and their respective confidence intervals) are classified in relation to a specified set of alert thresholds relevant to management.

These improvements have allowed us to:

- deliver an accurate, powerful and robust framework for data analysis that maximises statistical power (and hence the inferences that can robustly be made) while accounting for data noise

- distinguish between short- and long-term changes in garden bird counts within time frames and at spatial scales relevant to management – these garden bird counts include native species that government agencies have responsibility for, and introduced species that can signal changes in the health of the environment that otherwise might be missed
- produce comparable metrics in a cost-effective manner to inform management at different scales (national, regional, local), although the weaker evidence categories for local scales do highlight the need to sustain the annual survey rate but increase local participation rates to ensure the NZGBS can better inform local conservation efforts.

Recommended next steps

- Future NZGBS campaigns should aim to increase and retain participation in order to increase the accuracy of trends measured at local scales where community groups and local authorities want to use the results to inform their management actions. Initiatives that could detract from survey participation should not be pursued.
- Improve the data editing process to set rules for flagging unusual counts for all species (rather than just a subset of species, as currently done) and store this information on the online Datastore.
- Focus future analyses on the fixed time frames (10-year and 5-year periods) to ensure the trend results are comparable across years. This could be expanded in the future to include longer-term trends (e.g. 15-year and 25-year periods).
- Investigate issues flagged for model fit and bootstrapping (in particular for grey warbler and welcome swallow).
- Invite a panel review so that priorities for future developments can be identified and current data editing, analysis and interpretation protocols can be established as a standard.
- Future developments should consider adding new covariates to the base models to better account for variance in counts among spatial units. Candidate covariates for each urban rural area (or, if feasible, garden) could include measures of local landcover matrix (e.g. sourced from the Landcover Database) and predator control activities (e.g. distance to nearest sanctuary). In recent years, NZGBS participants have provided more detailed information on bird-feeding activities as well as the size and composition of survey areas; base models for the relevant periods should be adapted to include these covariates and investigate their influence on bird counts.

1 Purpose of this report

This report summarises the data legacy, editing, analysis and interpretation protocols for *State of NZ Garden Birds 2018 | Te Āhua o ngā Manu o te Kāri i Aotearoa* (MacLeod, Howard, Gormley, et al. 2019), which are as follows:

- editing the raw bird count data ready for analysis
- calculating changes in bird counts over the last 10-year and 5-year periods 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.

2 Source data

Our analysis is based on annual NZ Garden Bird Survey (NZGBS) records gathered from gardens by volunteers nationwide over the last 10-year and 5-year periods 2008–18 (n = 34,686 records) and 2013–18 (n = 20,274 records).

2.1 Data editing

The raw data gathered by the NZGBS (Spurr 2018; Spurr et al. 2018a, 2018b, 2019) and the edited data set (MacLeod 2019) used to produce this report are all stored in the restricted NZGBS collection on the Manaaki Whenua – Landcare Research online DataStore.[4]

Data for the period 2008–16 were edited using a combination of manual and automated processes (Howard et al. 2017; MacLeod et al. 2017); data for 2017 and 2018 were edited using standardised protocols in R (MacLeod et al. 2018; MacLeod 2019).

NZGBS records for all years were classified according to 2018 Statistics NZ spatial boundary layers[5] (region, territorial authority, urban rural).[6] 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 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.

---

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

[5] https://datafinder.stats.govt.nz/layer/92201-meshblock-higher-geographies-2018-high-definition/

[6] For definitions, see: http://archive.stats.govt.nz/methods/classifications-and-standards/classification-related-stats-standards/geographic-areas/pg4.aspx

2.2 Variation in sampling effort

For the period 2008 to 2018 the annual number of records ranges from 1,688 to 4,378, equivalent to 0.11% to 0.28% of all New Zealand gardens surveyed per year (MacLeod & Spurr 2019). For both data sets considered in our analysis, cumulative coverage of region, territorial authority and urban rural units is ≥70% (Table 1).

Table 1. Cumulative coverage of Statistics NZ 2018 geographical units by the NZGBS 2008–18 (*n* = 34,686 records) and 2013–18 (*n* = 20,274 records) data sets, respectively

Statistics NZ 2018		*Number of variable levels*			*Percentage coverage*	
geographical boundary layer	*Variable name*	*Statistics NZ 2018*	*NZGBS 2013–18*	*NZGBS 2008–18*	*NZGBS 2013–18*	*NZGBS 2008–18*
Region	REGC2018_1	16	16	16	100%	100%
Territorial authority[7]	TA2018_V_1	67	66	66	99%	99%
Urban rural[8]	UR2018_V_1	711	495	535	70%	75%
Gardens[9,10]	-	1,570,386	13,879	21,425	0.88%	1.36%

Sampling effort varied across both regions and years within regions (Figure 1). The highest proportion of gardens surveyed was for Otago (c. 0.5% on average), a record it has maintained since 2010 (MacLeod & Spurr 2019). Only in six other regions (Tasman, Marlborough, Wellington, Nelson, Canterbury and Hawke's Bay) was the average proportion of gardens sampled >0.2% (Figure 1). Regions with large cities (Auckland, Canterbury, Wellington and Otago) tended to contribute a higher number of records than other areas. Notable increases in the proportion of gardens sampled were observed in Taranaki and Southland in 2018 compared to earlier years (MacLeod & Spurr 2019).

The highest proportions of gardens surveyed were, on average, within territorial authorities for Dunedin city, Kāpiti Coast, Waimate, Clutha, Waitaki and Central Otago (Figure 2). Only Dunedin City, Kāpiti Coast and Waimate achieved an average proportion of gardens sampled of ≥0.5%. The highest numbers of surveyed gardens were in districts encompassing large cities.

---

[7] Note that if region and territorial authority names are concatenated, then the number of levels increases (Statistics NZ 2018 data set: 89 levels; NZGBS 2008–18: 70 levels; NZGBS 2013–18: 69 levels).

[8] Note that if region, territorial authority and urban rural names are concatenated, then the number of levels increases (Statistics NZ 2018 data set: 722 levels; NZGBS 2008–18: 539 levels; NZGBS 2013–18: 498 levels).

[9] Garden identity for individual NZGBS records was derived using a set of standardised rules as part of the NZGBS data editing protocols, with overlapping gardens given the same identity.

[10] The total number of available gardens was derived from the number of occupied dwellings, as defined in the data source: Statistics NZ 2013 Census counts by 2018 Statistical Area 1. https://datafinder.stats.govt.nz/layer/92224-2013-census-counts-by-statistical-area-1-2018/

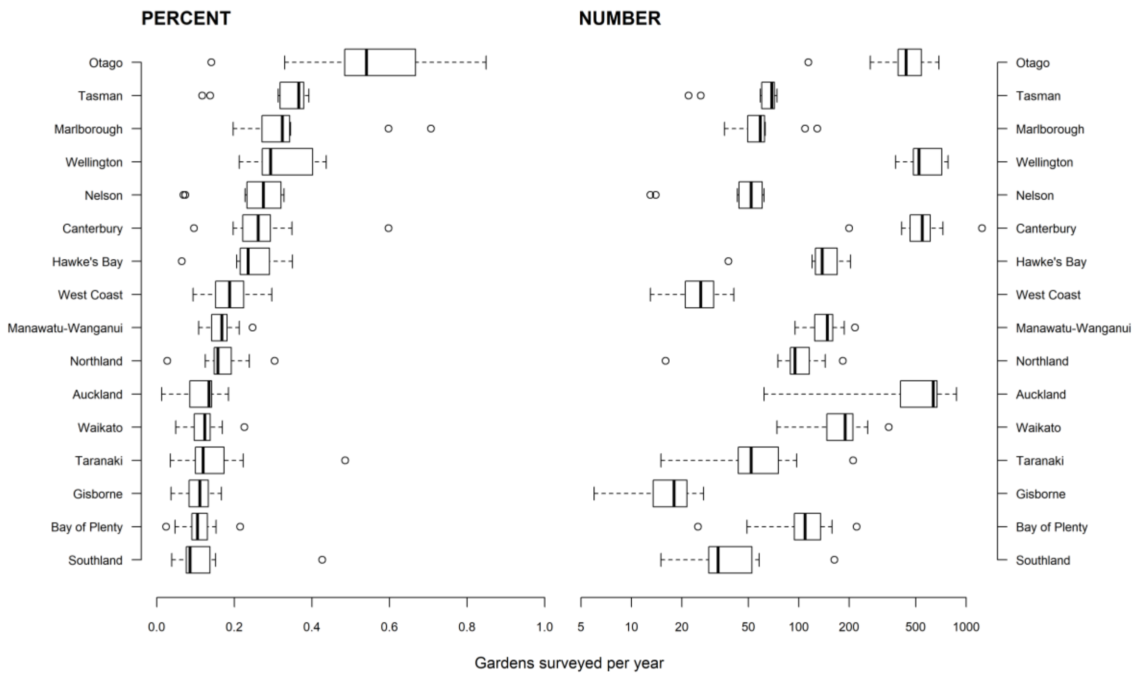

Figure 1. Variation among years (2008 to 2018) in the percentage and total number of gardens sampled within each region. Boxes contain the 25th and 75th percentiles, and the line within the box is the median. The whiskers extend to the most extreme data point (which is no more than 1.5 times the interquartile range from the box), and outlier points show the minimum and maximum values.

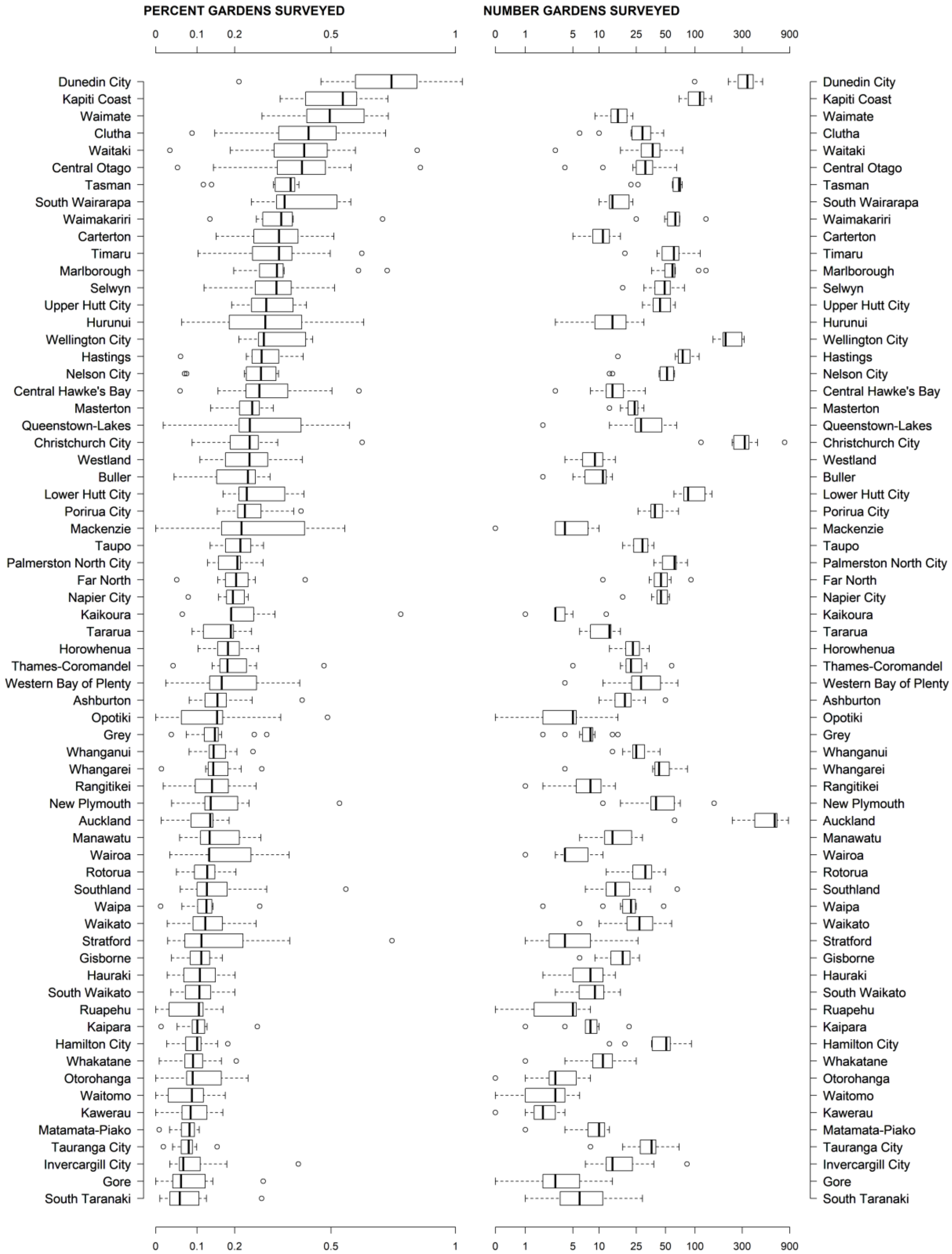

Figure 2. Annual variation among territorial areas or districts (*n* = 66) in the number of gardens surveyed within territorial areas between 2008 and 2018. Boxes contain the 25th and 75th percentiles and the line within the box is the median. The whiskers extend to the most extreme data point (which is no more than 1.5 times the interquartile range from the box), and outlier points show the minimum and maximum values.

2.3 Focal species

Our analysis is of 16 common and widespread bird species is shown in Table 2. Summary boxplots of the NZGBS bird counts highlight differences in the data characteristics among the species (Figures 3 & 4). 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 2. Sixteen common garden bird species considered for the NZGBS 2008–18 and 2013–18 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

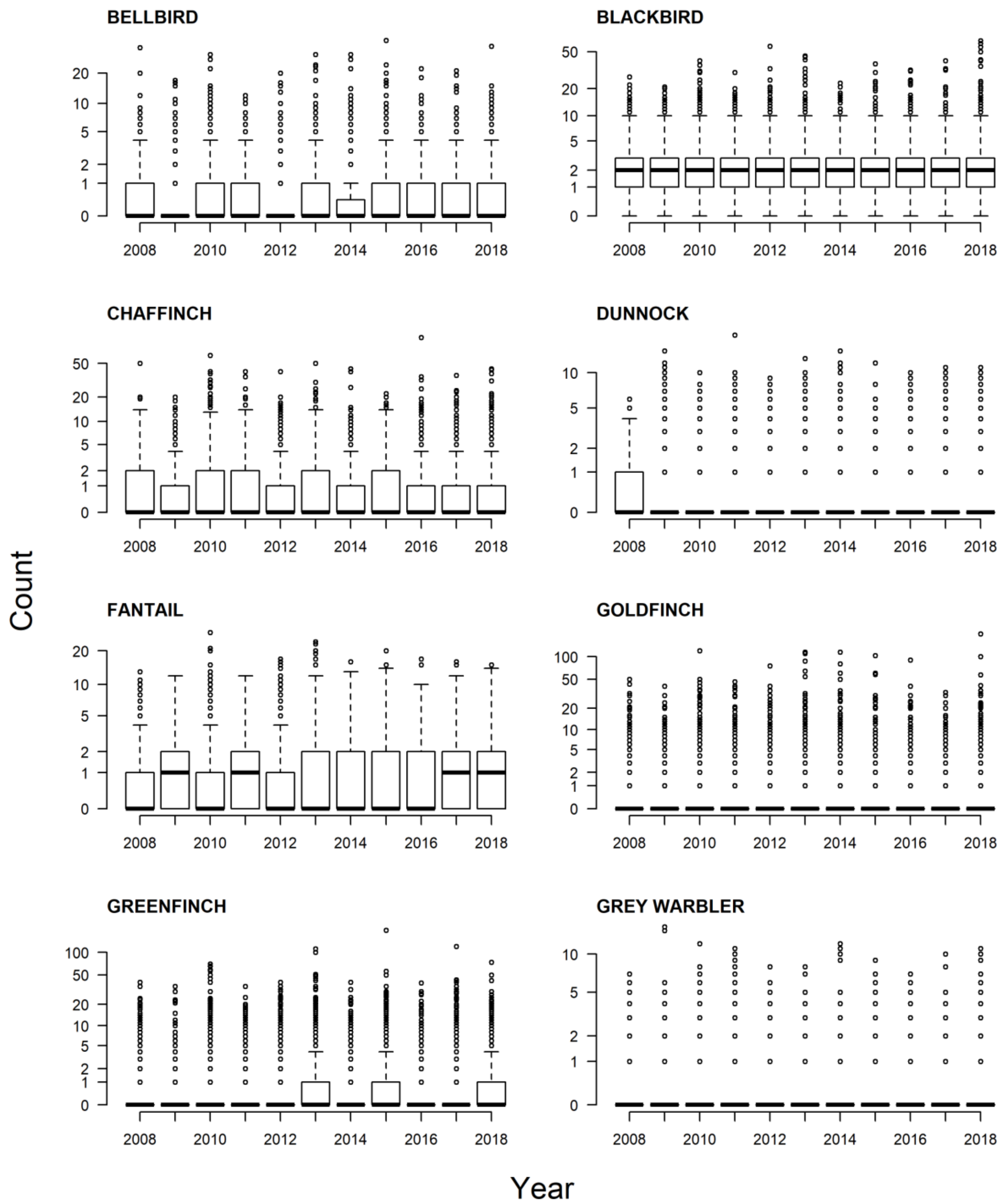

Figure 3. Box plots of bird counts for bellbird, blackbird, chaffinch, dunnock, fantail, goldfinch, greenfinch and grey warbler. Annual counts are presented for 2008 to 2018 (see MacLeod & Spurr 2019) for number of garden surveys per year). Boxes contain the 25th and 75th percentiles, and the line within 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.

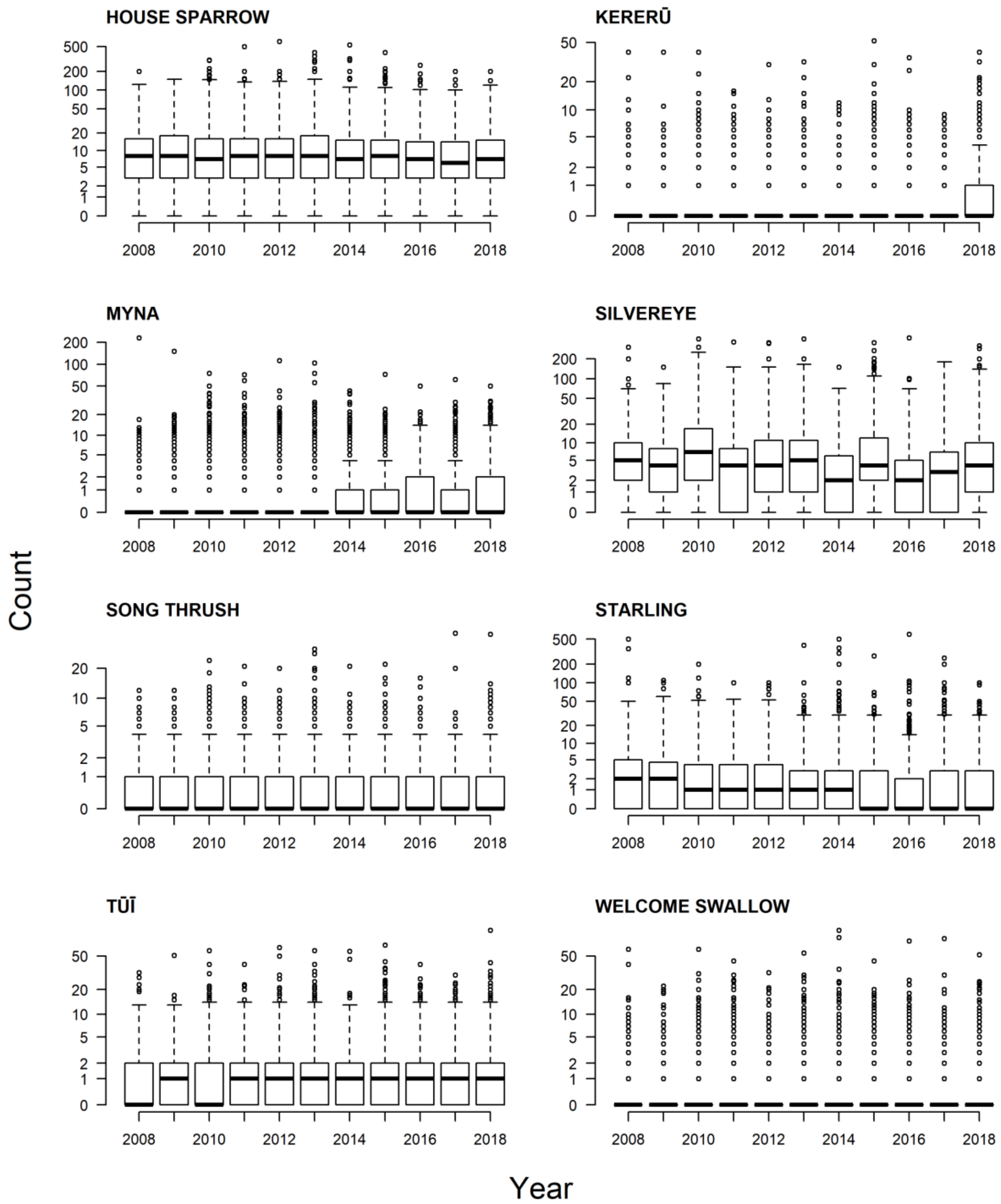

Figure 4. Box plots of bird counts for house sparrow, kererū, myna, silvereye, song thrush, starling, tūī and welcome swallow. Annual counts are presented for 2008 to 2018 (see MacLeod & Spurr 2019 for number of garden surveys per year). Boxes contain the 25th and 75th percentiles and the line within 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.

3 Trend analysis

Our analysis estimates changes in NZGBS counts over two periods: the last 10 and the last 5 years (2008–18 and 2013–18, respectively) and for 16 common garden birds at national, territorial authority and urban rural levels. This analysis protocol consisted of five key steps (adapted from MacLeod, Howard, Green et al. 2019):

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.

3.1 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 3). Models were fitted for each species independently using the glmer function in the lme4 package (Bates et al. 2015) in R (R Core Team 2019).

Table 3. 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|RT) + (yS|RTU) + (1| RTUG)	Binomial
Count	~ yS + fUrb * fFed + (yS|R) + (yS|RT) + (yS|RTU) + (1| RTUG) + (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 3 & 4).

The fixed effects specified were:

- the year of the survey ('yS', continuous on a standardised scale from –5 to 5 for the 10-year period and –2.5 to 2.5 for the 5-year period)
- 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 number of birds, all models included random intercepts for four spatially nested variables: Region ('R'), Territorial Authorities ('RT'), Urban-Rural ('RTU') and Garden Identity ('RTUG'); the number of levels for each spatial scale and data set are presented in Table 1. To account for spatial variation in trends at three scales (region, territorial authority and urban rural area), 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[11], small, and high counts in the response variable (Harrison 2014). (See Table 3 for detailed model specifications.)

3.2 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 urban rural area by adding the intercepts and slopes for the urban rural area ('yS|RTU') 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 for each area, respectively.

2 The urban rural trend estimates were weighted according to the number of gardens[12] within the unit (as a proportion of the national total[12]).

3 Territorial authority, region and national trend estimates were derived by calculating the weighted averages of the relevant subset of urban rural areas.

3.3 Parametric bootstrap

Estimating uncertainties (or confidence intervals) in weighted trend estimates is not straightforward, so we used parametric bootstrap.[13] Using the fitted based model as a starting point, we simulated new data, and repeated the mixed model fitting and weighted

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

[12] Where the number of gardens was assumed to be proportional to the number of occupied dwellings as defined in the data source: Statistics NZ 2013 Census counts by 2018 Statistical Area 1. https://datafinder.stats.govt.nz/layer/92224-2013-census-counts-by-statistical-area-1-2018/

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

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 0.9 and 28.7 hours to run per species on the Google Cloud platform[14] (24 cores vCPU, 90 GB memory; Table 4).

Table 4. Time taken to run a single bootstrap run, and then projected and actual times taken for 1,001 bootstrap runs per species on Google Cloud. Times are in total CPU core hours (time taken × number of cores; approximately equivalent to time taken on a single core CPU) to account for the varying number of cores used across models. The projected estimate is the base-model running time multiplied by 1,001.

Species	Error distribution	2008–18			2013–18		
		Base model (seconds)	1,001 bootstrap simulations (hours)		Base model (seconds)	1,001 bootstrap simulations (hours)	
			Projected	Actual		Projected	Actual
Bellbird	Binomial	125	34.9	113.1	45	12.5	38.4
Blackbird	Poisson	318	89.1	324.8	266	74.4	121.6
Chaffinch	Binomial	153	42.5	52.4	28	7.7	22.9
Dunnock	Binomial	100	27.7	64.5	244	68.3	32.5
Fantail	Binomial	223	62.0	59.2	46	12.8	25.3
Goldfinch	Binomial	71	20.0	54.4	41	11.5	28.5
Greenfinch	Binomial	108	30.0	60.9	45	12.5	27.7
Grey warbler	Binomial	645	180.5	121.1	121	33.9	78.1
House sparrow	Poisson	364	101.9	302.1	155	43.5	98.9
Kererū	Binomial	214	59.5	82.4	52	14.7	34.1
Myna	Binomial	81	22.5	62.3	31	8.8	28.0
Silvereye	Poisson	323	90.4	297.3	87	24.3	106.4
Song thrush	Binomial	92	25.9	48.5	35	9.9	22.1
Starling	Poisson	363	109.9	691.2	145	40.5	119.5
Tūī	Binomial	188	52.5	86.9	47	13.1	36.3
Welcome swallow	Binomial	107	29.9	143.2	37	10.4	87.7

3.4 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

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

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 2018) and y_{si1} is the bird count estimate for the first year of the NZGBS (2008 or 2013).

3.5 Model diagnostics

First, we compared annual national estimates of species counts calculated based on the:

- annual national mean of the raw counts
- weighted median counts (or presence), where the annual median for each spatial unit (R\T\U\SA2, where 'SA2' is the NZ Statistics unit, Statistical Area 2) was multiplied by the proportion of gardens in the spatial unit (i.e. the number of gardens per spatial unit divided by the total number of gardens[15]) then summed to get the weighted median; the median is presented (rather than the mean) because it reduces the influence of outlier points on the average estimate
- weighted annual point estimates for the 10-year and 5-year periods, which were extracted from the base models and weighted as above for median counts.

For most species, weighted median counts[16] are lower than those estimates derived from raw counts. This is in part because weighting accounts for the variation in sampling effort among spatial units over time (Figure 5). Annual point estimates are broadly aligned for both the 10-year and 5-year periods. For three species (house sparrow, silvereye and starling) the models tended to underestimate the annual point estimates relative to the weighted medians but accurately reflect the underlying trends. This signals that these models are suitable for the purposes of reporting trends but that future analyses need to identify other environmental covariates to produce more accurate annual point estimates; based on our current model specifications, estimates for spatial units with high counts, but few datapoints, will shrink towards the estimate for their associated coarser-level spatial unit.

[15] The total number of gardens was the sum of the number of gardens among sampled spatial units (i.e. any spatial unit where a median count was not available, its gardens were excluded from the national total number of gardens).

[16] Note that weighted medians are calculated at the Statistics NZ's Statistical Area 2 units; hence if an area has a large count and is the only observation at that unit, it will still have a large, although diluted, influence on the weighted mean.

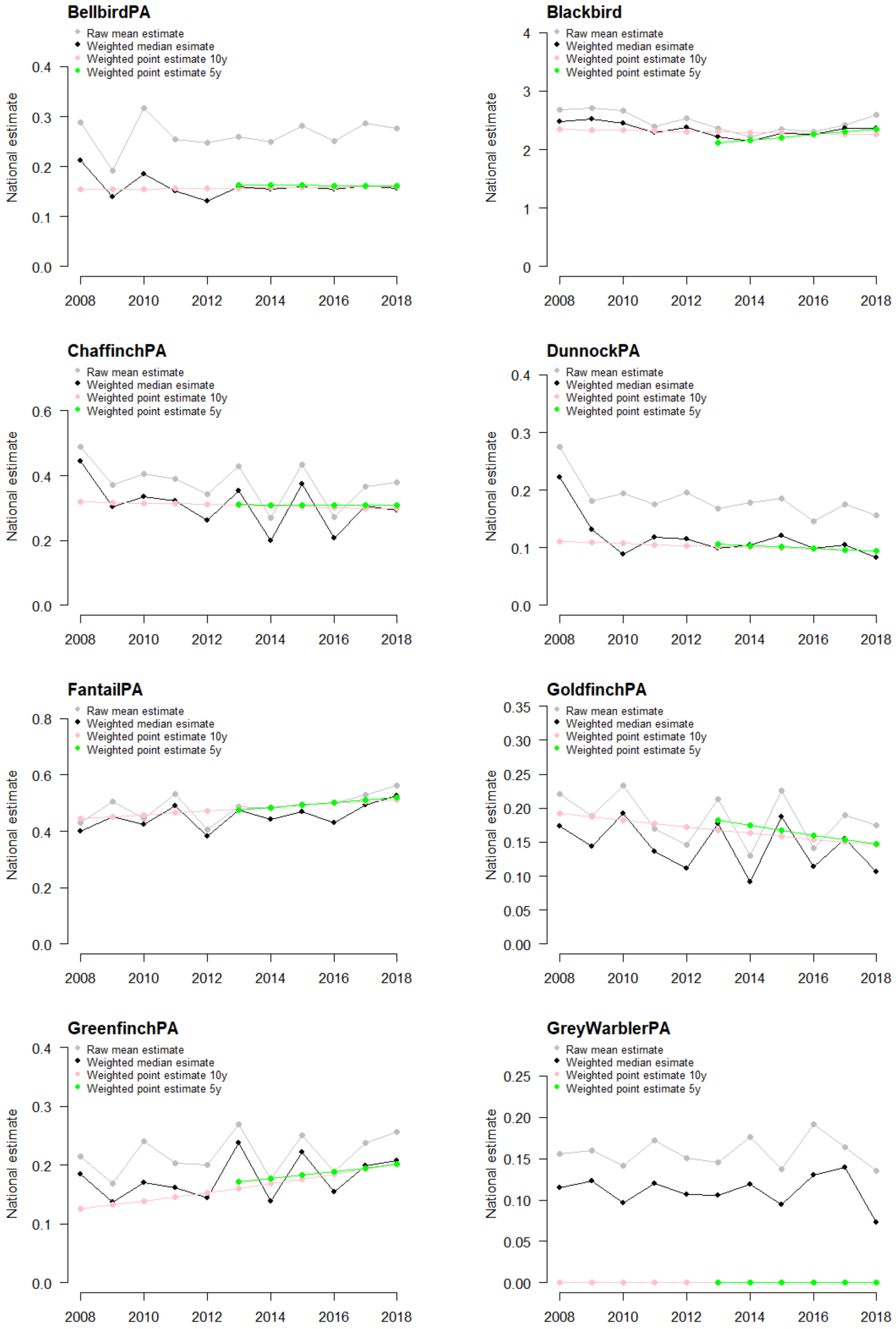

Figure 5 (continued following page). National annual estimates of the average count of birds per garden for each species for a 10-year period (2008 to 2018) showing the raw mean, weighted median and weighted point estimates (derived from the base models for the 10-year and 5-year periods). Estimates are based on counts unless the species label includes ‘PA’, in which cases counts were converted into presence/absence data.

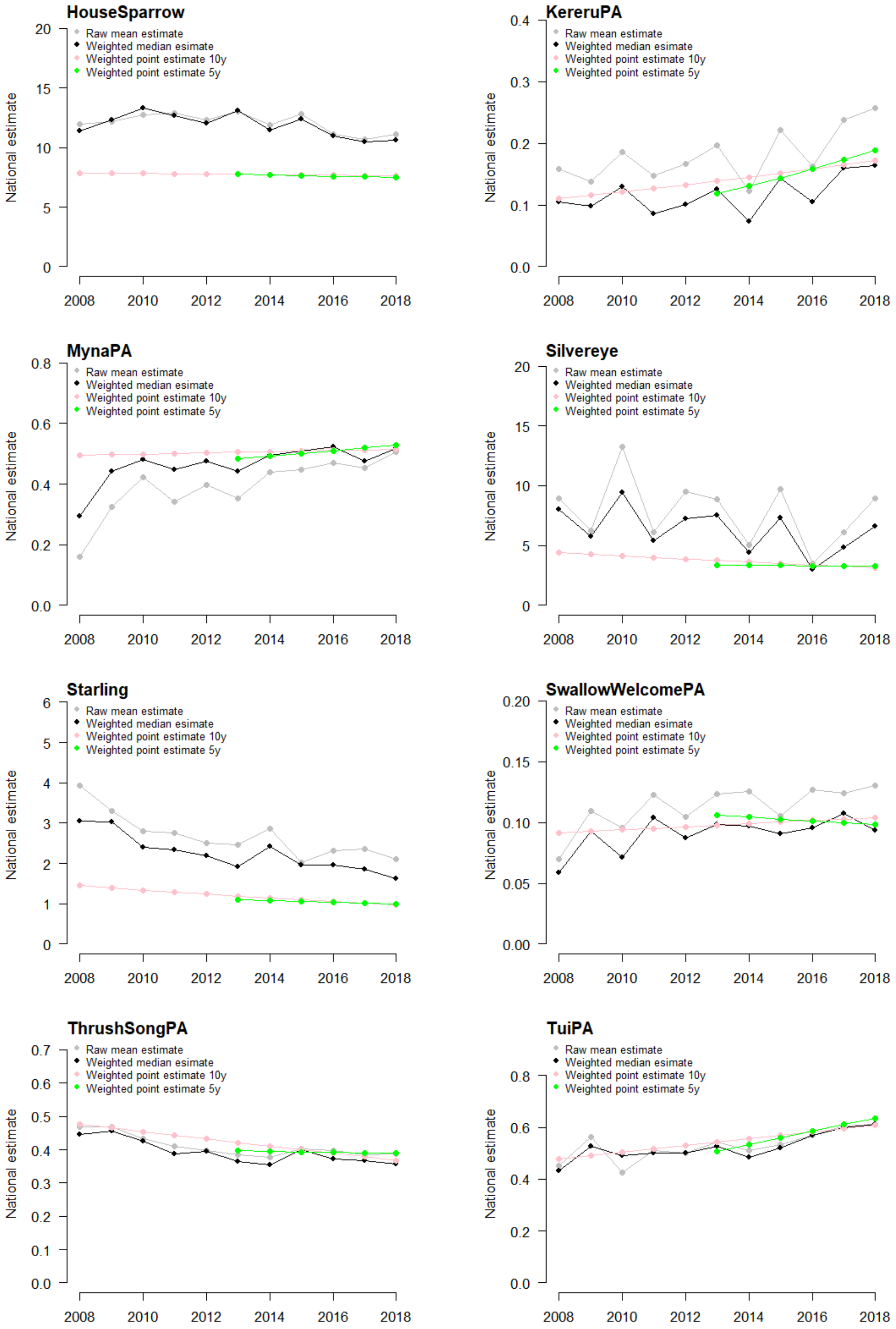

Figure 5 (continued).

Adding new covariates (aligned to each spatial unit to capture reasons why they differ from their surrounding units) to our models as fixed effects should allow the estimates to vary more than currently they do. Model fit for grey warbler is poor, probably due to zero-inflated data.

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 for both the 10-year and 5-year periods, were therefore excluded from the current analyses.

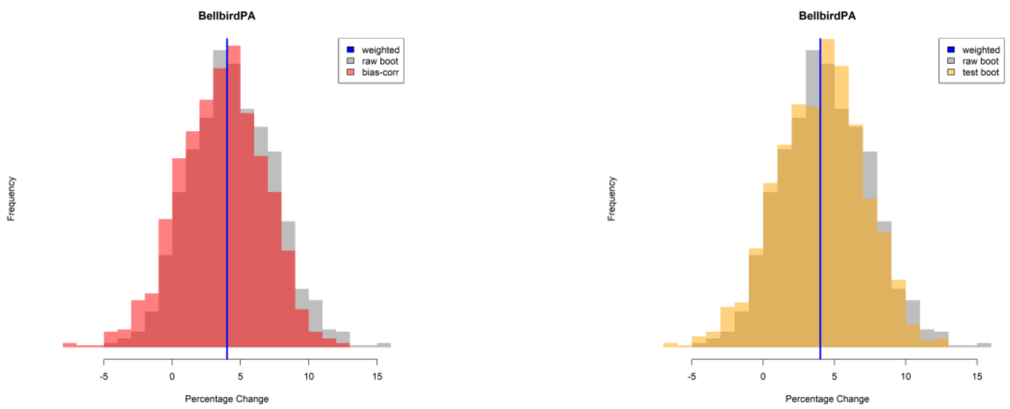

Figure 6 (continued following pages). Diagnostic plots for each species for a 10-year period (2008 to 2018) showing the weighted point estimates (derived from the base model; blue vertical lines), raw weighted bootstrap replicates ('raw boot'; grey histograms) and bias-corrected bootstrap replicates ('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.

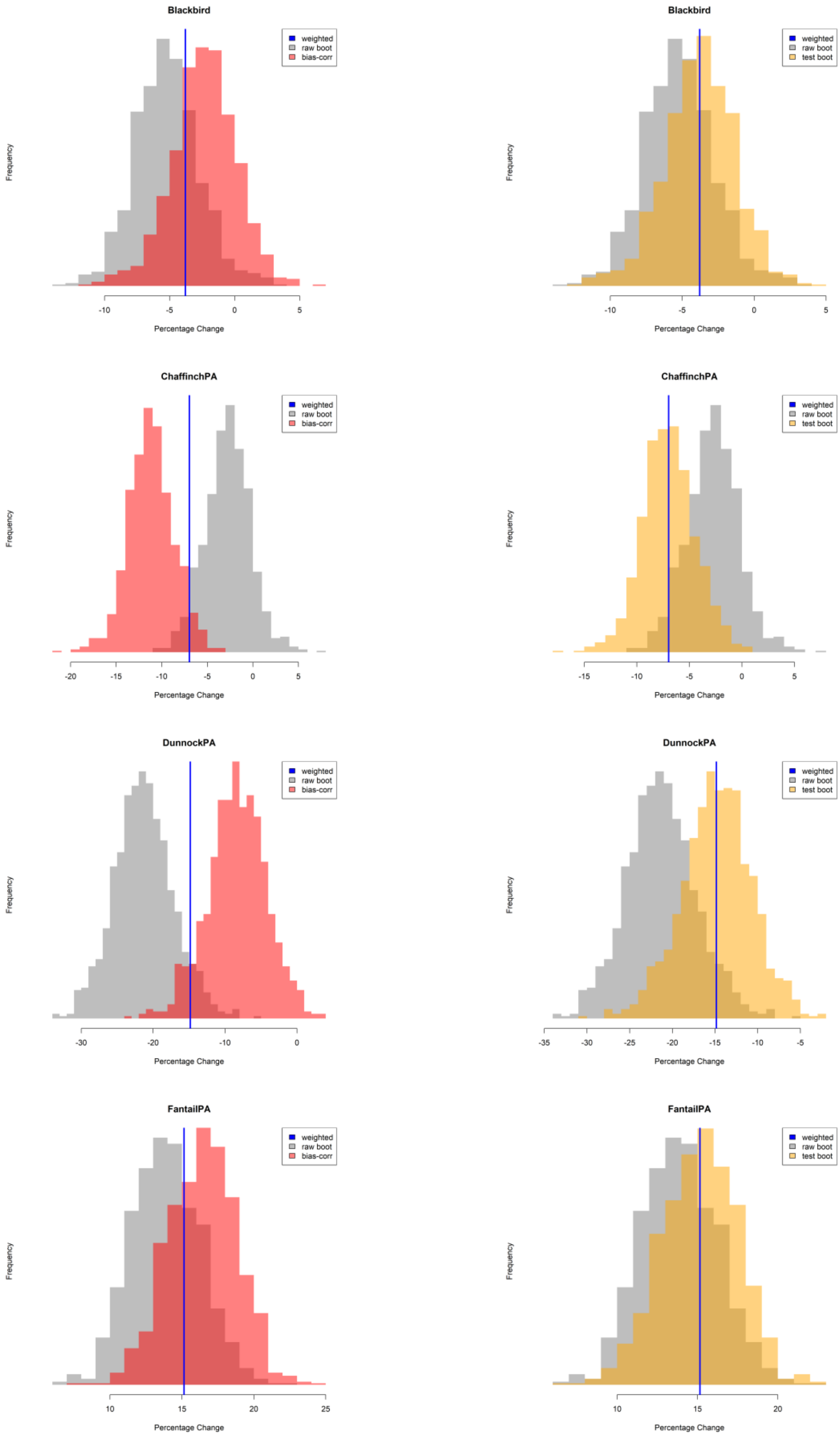

Figure 6 (continued).

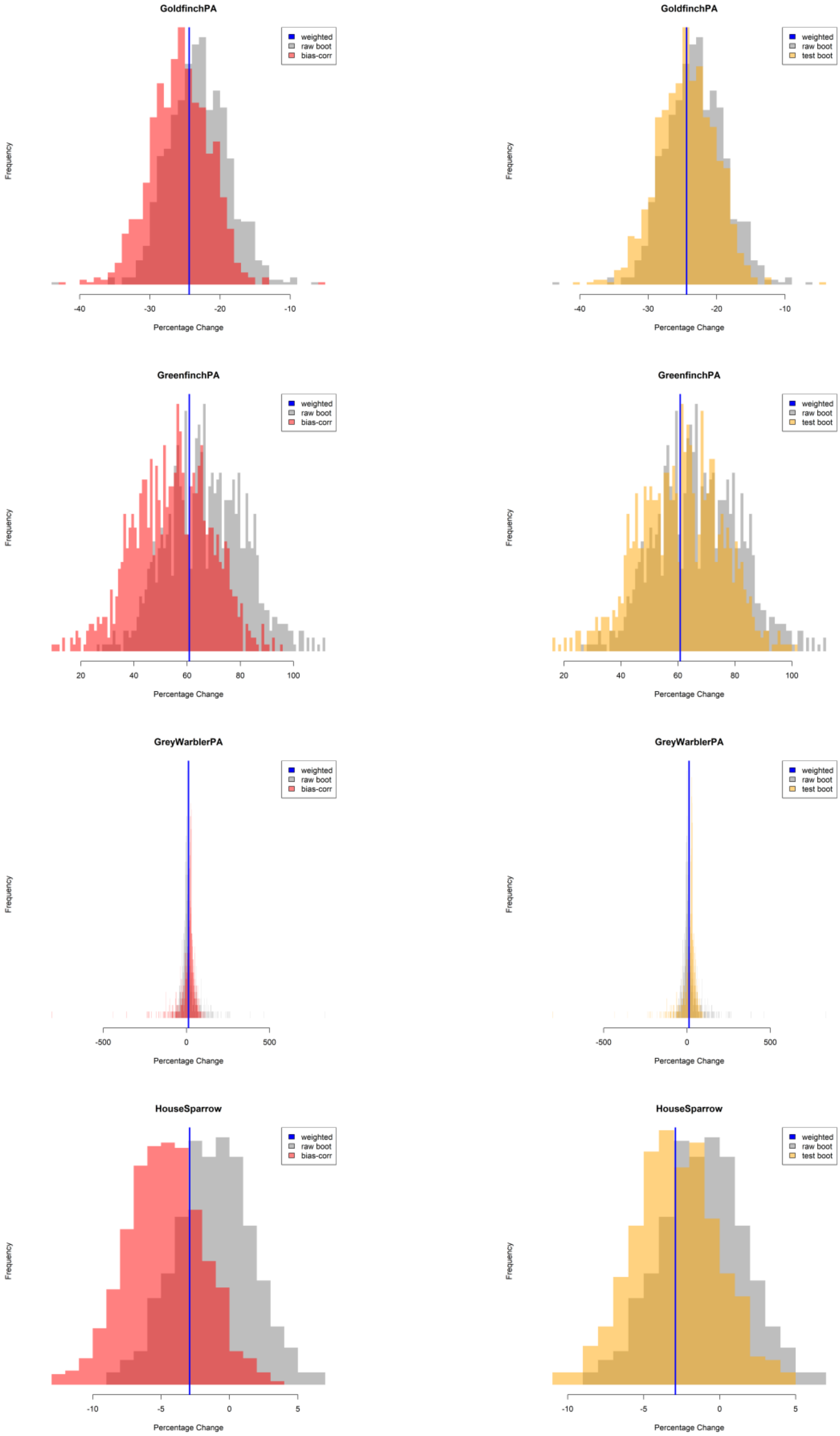

Figure 6 (continued).

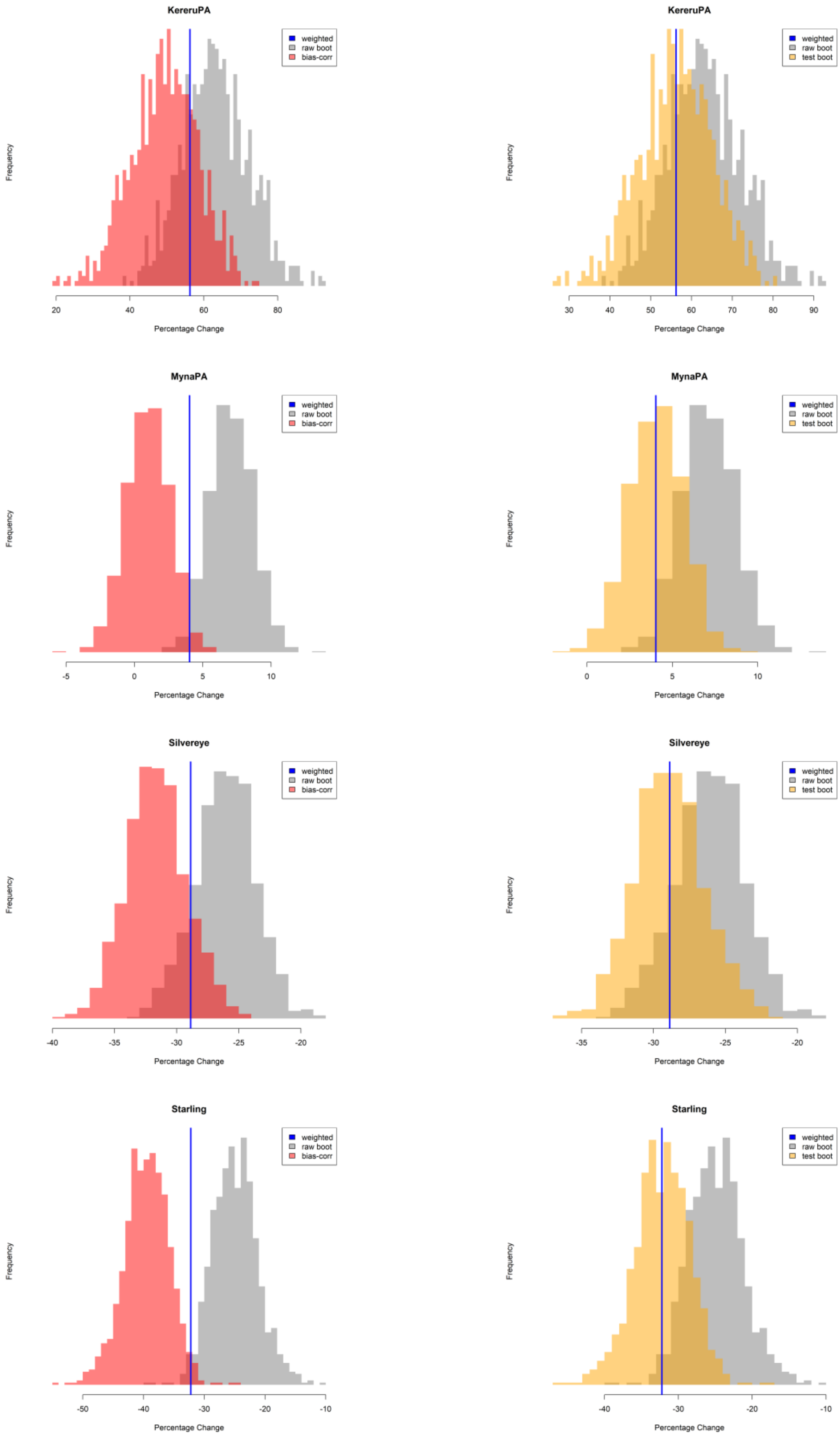

Figure 6 (continued).

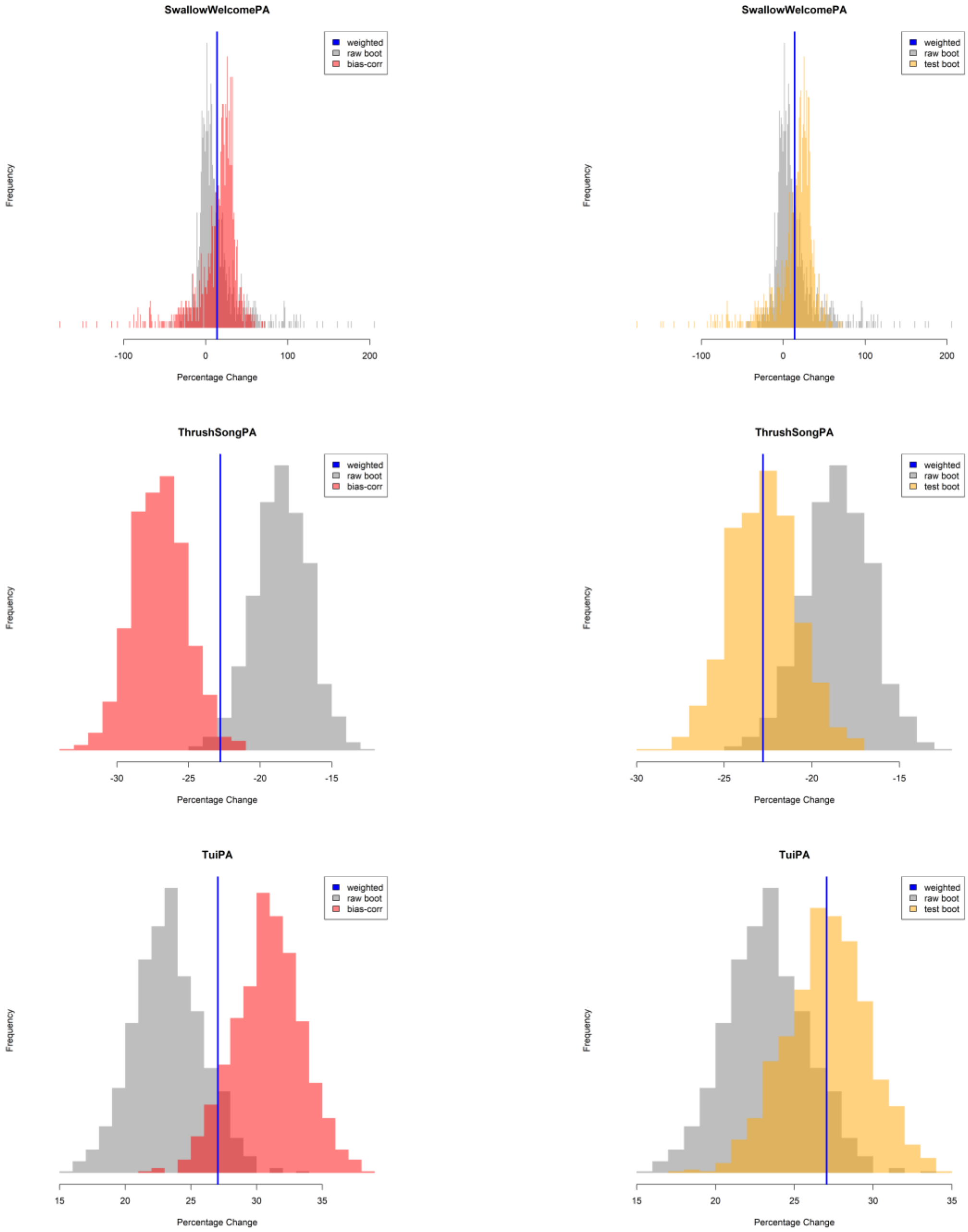

Figure 6 (continued).

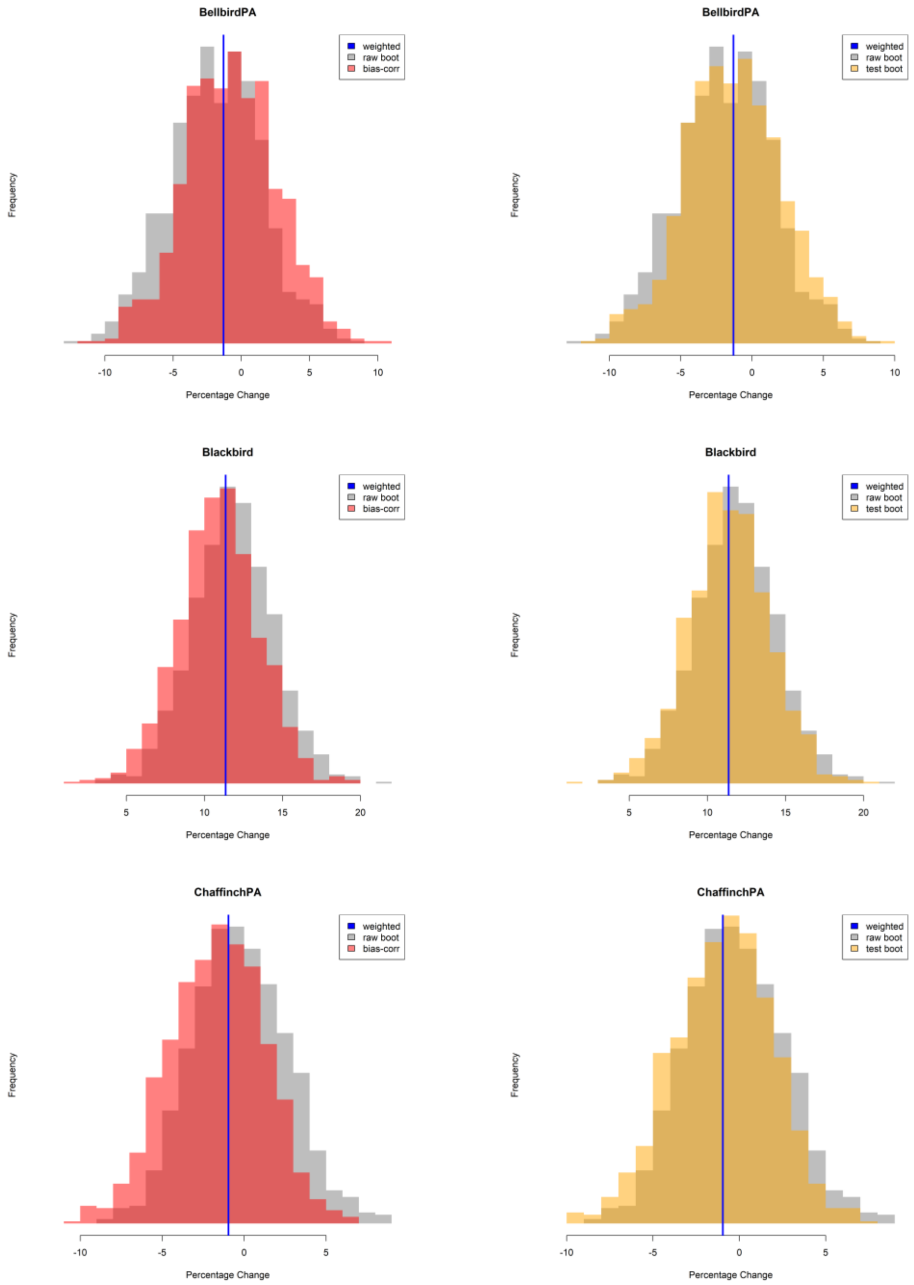

Figure 7 (continued following pages). Diagnostic plots for each species for a 5-year period (2013 to 2018), showing the weighted point estimates (derived from the base model; blue vertical lines), raw weighted bootstrap replicates ('raw boot'; grey histograms) and bias-corrected bootstrap replicates ('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.

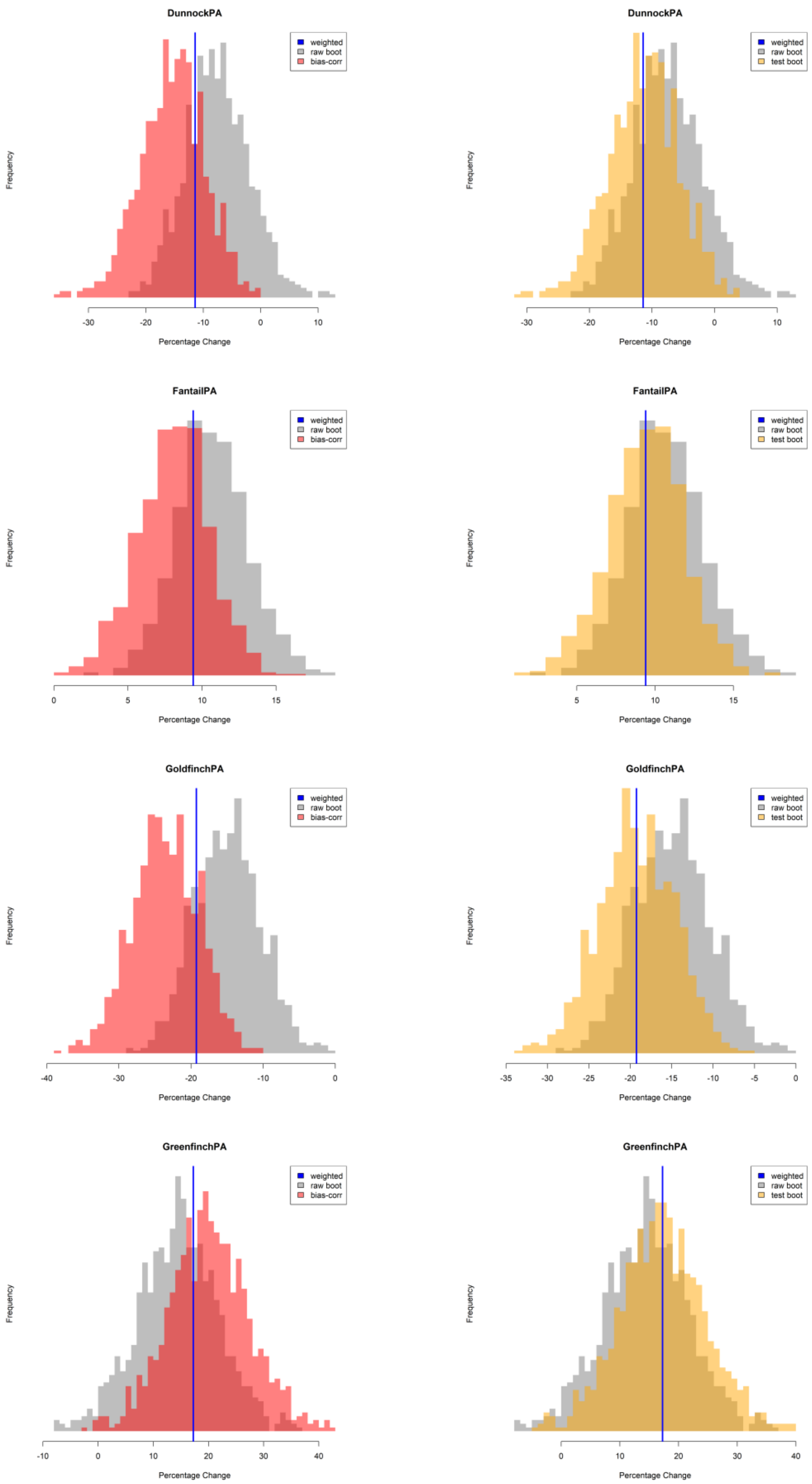

Figure 7 (continued).

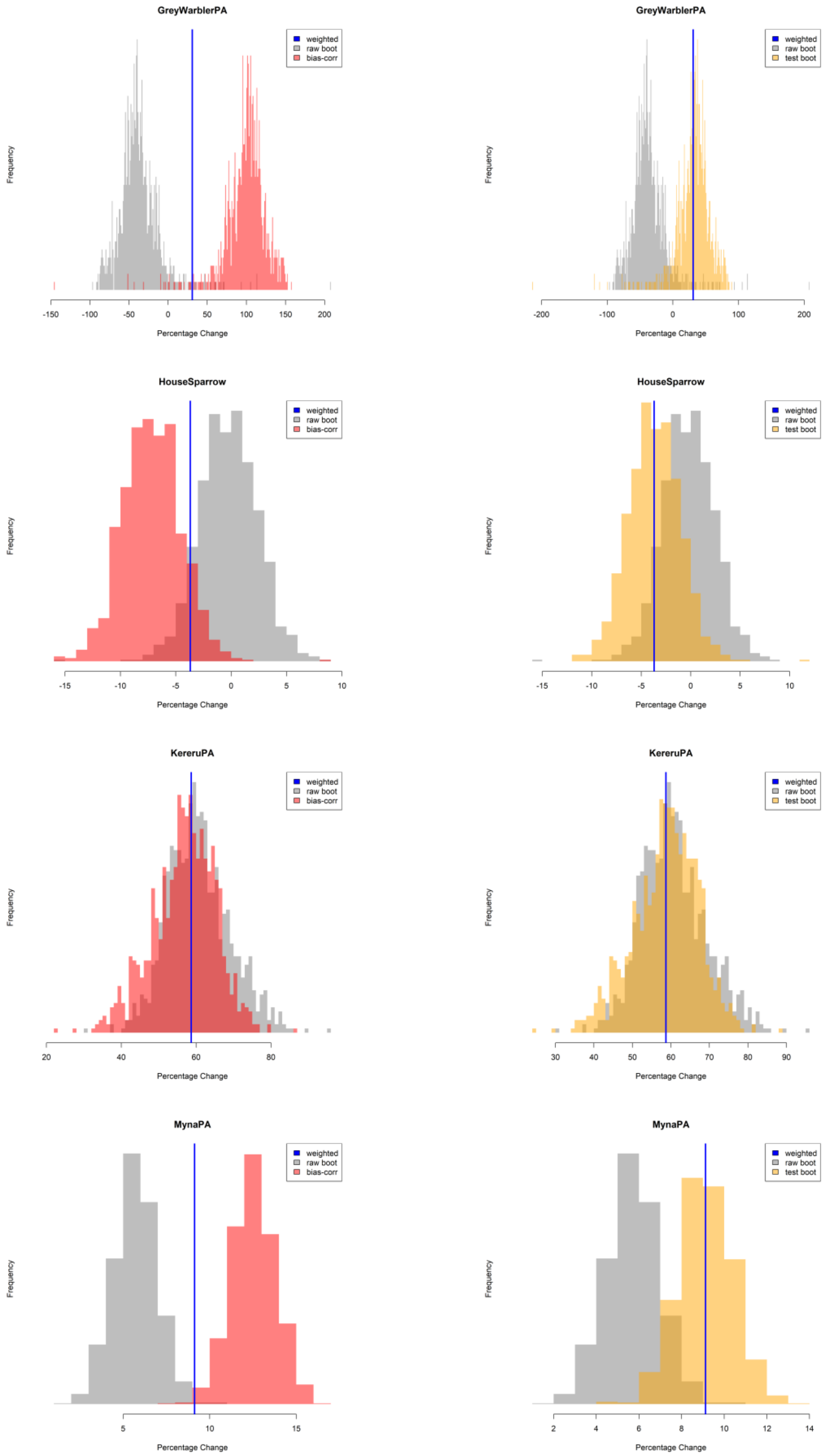

Figure 7 (continued).

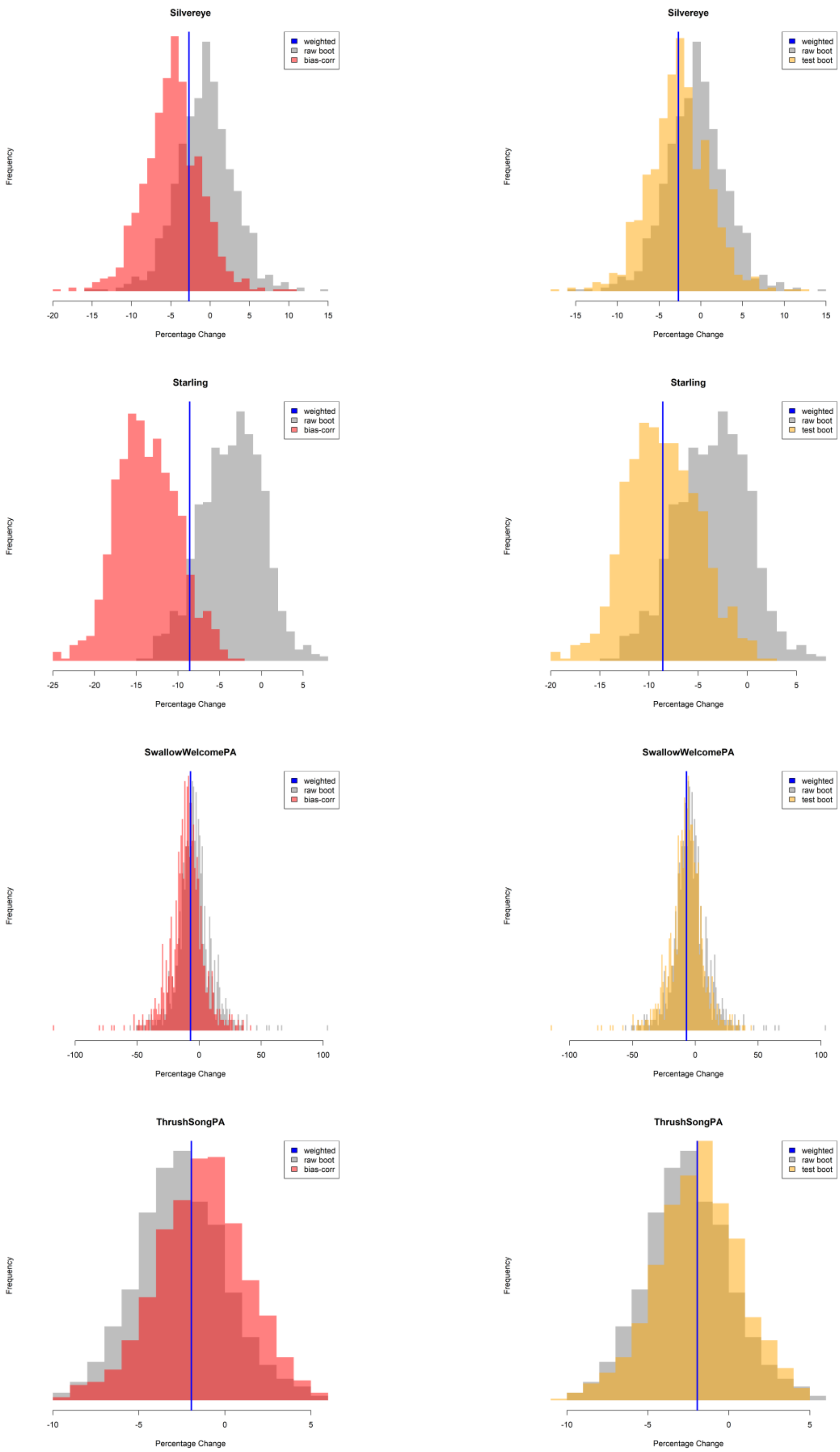

Figure 7 (continued).

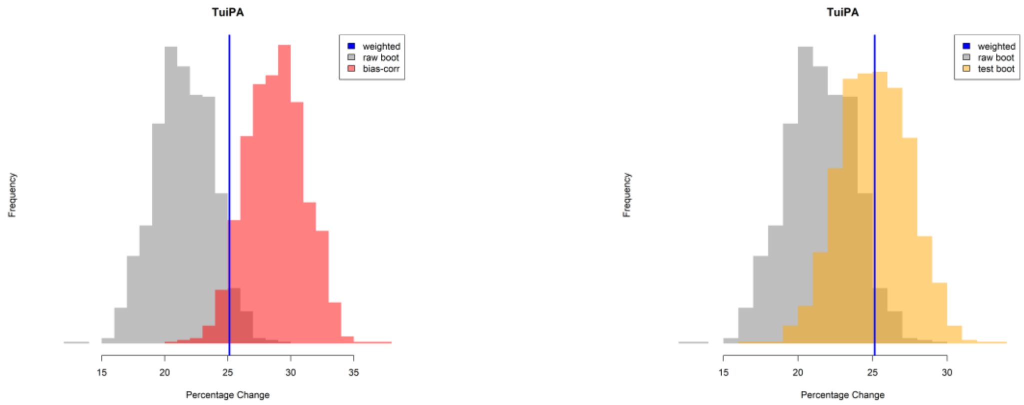

Figure 7 (continued).

4 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[17] 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 timescales depending on the data available (ideally the most recent 25-, 10- or 5-year periods; Baillie & Rehfisch 2006). These thresholds, which were identified *a priori*, 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

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

estimates that meet the trend threshold criteria and/or overlap zero. Species with lower variance and greater sample sizes will have stronger evidence.

4.1 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 these classifications was then evaluated using the standardised criteria (Table 5), taking into consideration the distribution of the bootstrap estimates and whether they overlapped zero or not.

Table 5. 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%

For both the 2008–18 and 2013–18 NZGBS national data sets, for example, we classified eight of the 14 species as declining and the remainder as increasing at the national scale (Table 6). There was strong or very strong evidence to support those trend direction classifications for all species within the 10-year period and for all but four species within the 5-year period. For the remaining four species (silvereye, song thrush, bellbird and chaffinch) in the 5-year period, the 10–90% quantile range for 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, and for the 10-year period than for the 5-year one (Figure 8).

Table 6. Summary of bootstrap results and associated trend classification for 14 garden bird species at the national scale (based on NZGBS data for the 10-year and 5-year periods 2008–18 and 2013–18; see Table 3 for model specifications for each species)

Period	*Species*	*% bootstrap estimates*		*Bootstrap estimates include zero*	*Trend classification*	
		Decline	*Increase*		*Trend direction*	*Strength of evidence*
10y	Starling	100	0	0	Decline	Very strong
	Silvereye	100	0	0	Decline	Very strong
	Dunnock	100	0	0	Decline	Very strong
	Goldfinch	100	0	0	Decline	Very strong
	Song thrush	100	0	0	Decline	Very strong
	Chaffinch	99	0	0	Decline	Very strong
	Blackbird	94	6	0	Decline	Very strong
	House sparrow	85	15	0	Decline	Strong
	Bellbird	9	90	0	Increase	Strong
	Fantail	0	100	0	Increase	Very strong
	Kererū	0	100	0	Increase	Very strong
	Tūī	0	100	0	Increase	Very strong
	Greenfinch	0	100	0	Increase	Very strong
	Myna	0	99	0	Increase	Very strong
5y	Goldfinch	100	0	0	Decline	Very strong
	Dunnock	98	1	0	Decline	Very strong
	Starling	98	1	0	Decline	Very strong
	House sparrow	92	7	0	Decline	Very strong
	Silvereye	77	22	1	Decline	Very weak
	Song thrush	77	22	1	Decline	Very weak
	Bellbird	65	34	1	Decline	Very weak
	Chaffinch	61	38	1	Decline	Very weak
	Greenfinch	1	98	0	Increase	Very strong
	Fantail	0	100	0	Increase	Very strong
	Kererū	0	100	0	Increase	Very strong
	Tūī	0	100	0	Increase	Very strong
	Blackbird	0	100	0	Increase	Very strong
	Myna	0	100	0	Increase	Very strong

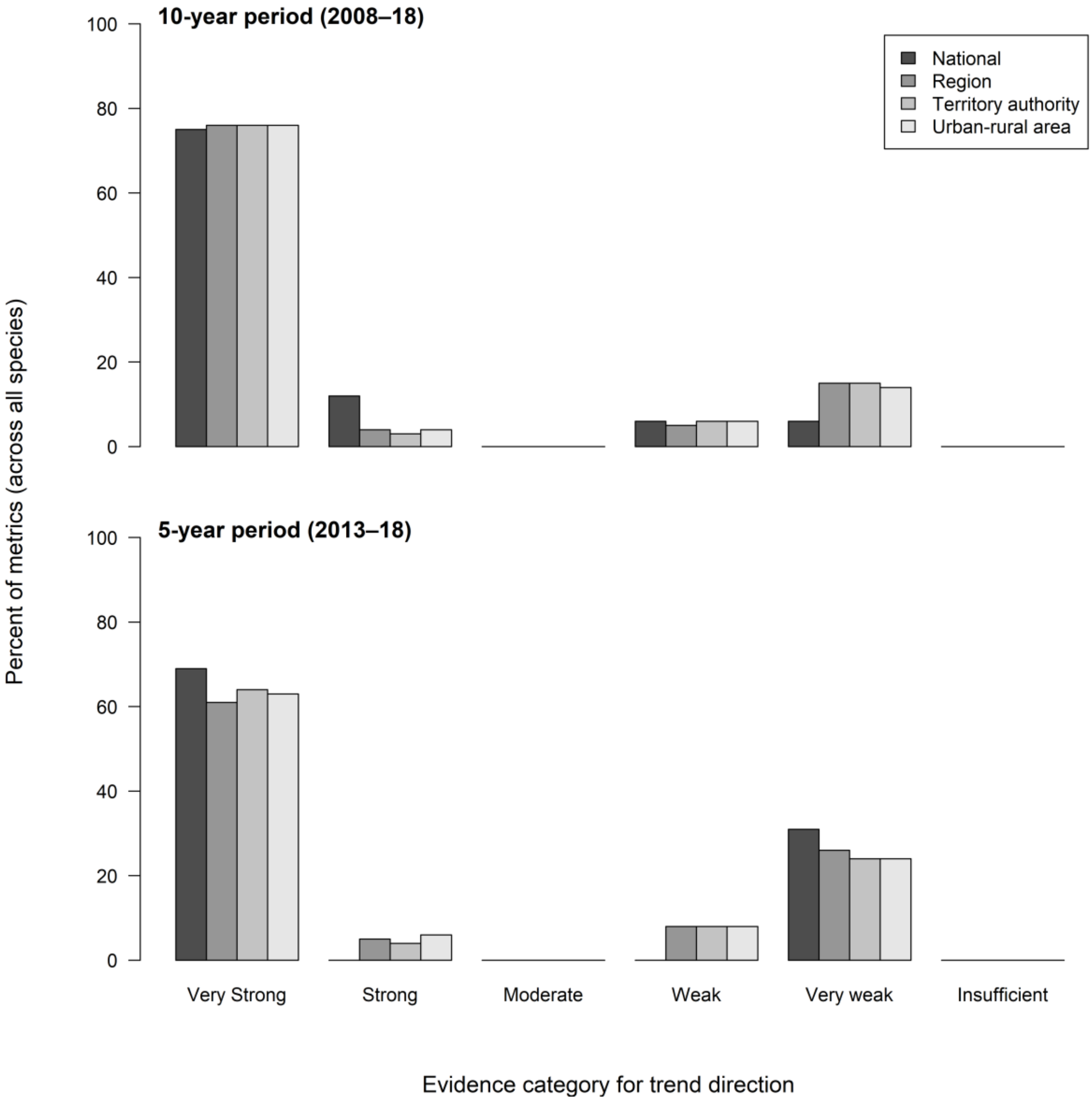

Figure 8. Evidence categories for trend direction classification across 14 species for each spatial scale and period.

4.2 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 7). We then evaluated the evidence to support these trend classifications (Table 8), 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 7).

Table 9, for example, summarises the NZGBS national trend classification for the period 2008–18. Bird counts have declined moderately for two species (silvereye and starling), undergone a shallow decline for three (dunnock, goldfinch and song thrush), changed little or not at all for five (chaffinch, blackbird, house sparrow, myna, and bellbird), and undergone a shallow increase for two (fantail and tūī) and a moderate increase for two (kererū and greenfinch). For 10 species (starling, silvereye, goldfinch, song thrush, blackbird, house sparrow, myna, bellbird, fantail and tūī), the evidence for the trend size categorisation was very strong for this period. For the remaining species the strength of evidence for the trend size category ranged from moderate (kererū and greenfinch) to strong (chaffinch and dunnock).

Table 10 shows similar information for the 5-year period, where bird counts have undergone moderate declines for one species (goldfinch), shallow declines for two species (dunnock and starling), changed little or not at all for five species (house sparrow, silvereye, bellbird, song thrush and chaffinch,) and undergone a shallow increase for four species (myna, fantail, blackbird and greenfinch), a moderate increase for tūī, and a rapid increase for kererū. For this period, the strength of evidence for these trend size classifications was strong or very strong for all but two species: silvereye and house sparrow, classified as moderate and weak, respectively.

Broadly, the strength of evidence for trend size was stronger at the national scale than at finer spatial scales, and for the 10-year period than for the 5-year one (Figure 9).

Table 7. Criteria used to classify long-term population trends for New Zealand's garden birds based on the point estimate derived from the base models of percentage change in bird counts

Trend size classification	*Threshold range*				*Threshold colour*
	10-year period		*5-year period**		
	Lower limit	*Upper limit*	*Lower limit*	*Upper limit*	
Rapid decline	≥ –∞	≤ –50%	≥ –∞	≤ –29%	Red
Moderate decline	> –50%	≤ –25%	> –29%	≤ –13%	Amber
Shallow decline	> –25%	≤ –10%	> –13%	≤ –5%	Light amber
Little or no change	> –10%	≤ +10%	> –5%	≤ +5%	Light green
Shallow increase	> +10%	≤ +50%	> +5%	≤ +22%	Dark green
Moderate increase	> +50%	≤ +100%	> +41%	≤ +41%	Light blue
Rapid increase	> +101%	≤ +∞	> +41%	≤ +∞	Dark blue

* These thresholds are calculated based on the same rate of annual change as used for the 10-year period.

Table 8. Classifying the strength of evidence to support the long-term trend classifications for New Zealand garden birds, where the threshold criterion for little or no change was >–10% but ≤+10%; for declining trend sizes it was less than or equal to the respective upper threshold (see Table 7); and for increasing trend sizes it was greater than the lower threshold for each size class (see Table 7)

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

Table 9. Classification of trends and associated trend alerts for 14 garden bird species (based on NZGBS data for the period 2008–18)

Species	***Median***	***Quantile estimates***		***% bootstrap estimates meet alert threshold criteria***							***Trend classification***			
				Decline				*Increase*			*Direction*		*Size*	
		10%	*90%*	*Rapid*	*Moderate*	*Shallow*	*No or little change*	*Shallow*	*Moderate*	*Rapid*	*Trend*	*Evidence*	*Trend*	*Evidence*
Greenfinch	61	42	79	0	0	0	0	24	76	0	Increase	Very strong	Moderate	Moderate
Kererū	56	44	67	0	0	0	0	23	77	0	Increase	Very strong	Moderate	Moderate
Tūī	27	23	30	0	0	0	0	100	0	0	Increase	Very strong	Shallow	Very strong
Fantail	15	12	18	0	0	0	2	98	0	0	Increase	Very strong	Shallow	Very strong
Bellbird	4	0	7	0	0	0	98	2	0	0	Increase	Strong	Little or no change	Very strong
Myna	4	2	6	0	0	0	100	0	0	0	Increase	Very strong	Little or no change	Very strong
House sparrow	–2	–6	0	0	0	1	99	0	0	0	Decline	Strong	Little or no change	Very strong
Blackbird	–3	–6	0	0	0	2	98	0	0	0	Decline	Very strong	Little or no change	Very strong
Chaffinch	–7	–10	–3	0	0	10	90	0	0	0	Decline	Very strong	Little or no change	Strong
Dunnock	–14	–20	–9	0	1	88	11	0	0	0	Decline	Very strong	Shallow	Strong
Song thrush	–22	–25	–20	0	11	89	0	0	0	0	Decline	Very strong	Shallow	Very strong
Goldfinch	–24	–29	–18	0	43	57	0	0	0	0	Decline	Very strong	Shallow	Very strong
Silvereye	–28	–31	–25	0	94	6	0	0	0	0	Decline	Very strong	Moderate	Very strong
Starling	–32	–36	–32	0	97.9	2.1	0	0	0	0	Decline	Very strong	Moderate	Very strong

Table 10. Classification of trends and associated trend alerts for 14 garden bird species (based on NZGBS data for the period 2013–18)

Species	*Quantile estimates*			*% bootstrap estimates meet alert threshold criteria*							*Trend classification*			
				Decline				*Increase*			*Direction*		*Size*	
	Median	*10%*	*90%*	*Rapid*	*Moderate*	*Shallow*	*No or little change*	*Shallow*	*Moderate*	*Rapid*	*Trend*	*Evidence*	*Trend*	*Evidence*
Kererū	59	47	68	0	0	0	0	0	3	97	Increase	Very strong	Rapid	Very strong
Tūī	25	22	28	0	0	0	0	9	92	0	Increase	Very strong	Moderate	Very strong
Greenfinch	17	8	26	0	0	0	5	70	25	0	Increase	Very strong	Shallow	Very strong
Blackbird	11	8	14	0	0	0	1	99	0	0	Increase	Very strong	Shallow	Very strong
Fantail	9	6	12	0	0	0	4	96	0	0	Increase	Very strong	Shallow	Very strong
Myna	9	7	10	0	0	0	0	100	0	0	Increase	Very strong	Shallow	Very strong
Chaffinch	0	–4	2	0	0	8	91	2	0	0	Decline	Very weak	Little or no change	Very strong
Song thrush	–1	–5	1	0	0	11	89	0	0	0	Decline	Very weak	Little or no change	Strong
Bellbird	–1	–5	3	0	0	12	84	3	0	0	Decline	Very weak	Little or no change	Strong
Silvereye	–2	–7	1	0	1	24	74	2	0	0	Decline	Very weak	Little or no change	Moderate
House sparrow	–3	–6	0	0	0	30	70	0	0	0	Decline	Very strong	Little or no change	Weak
Starling	–8	–13	–8	0	10	73	17	0	0	0	Decline	Very strong	Shallow	Strong
Dunnock	–11	–18	–4	1	36	51	12	0	0	0	Decline	Very strong	Shallow	Strong
Goldfinch	–19	–25	–13	2	90	8	0	0	0	0	Decline	Very strong	Moderate	Very strong

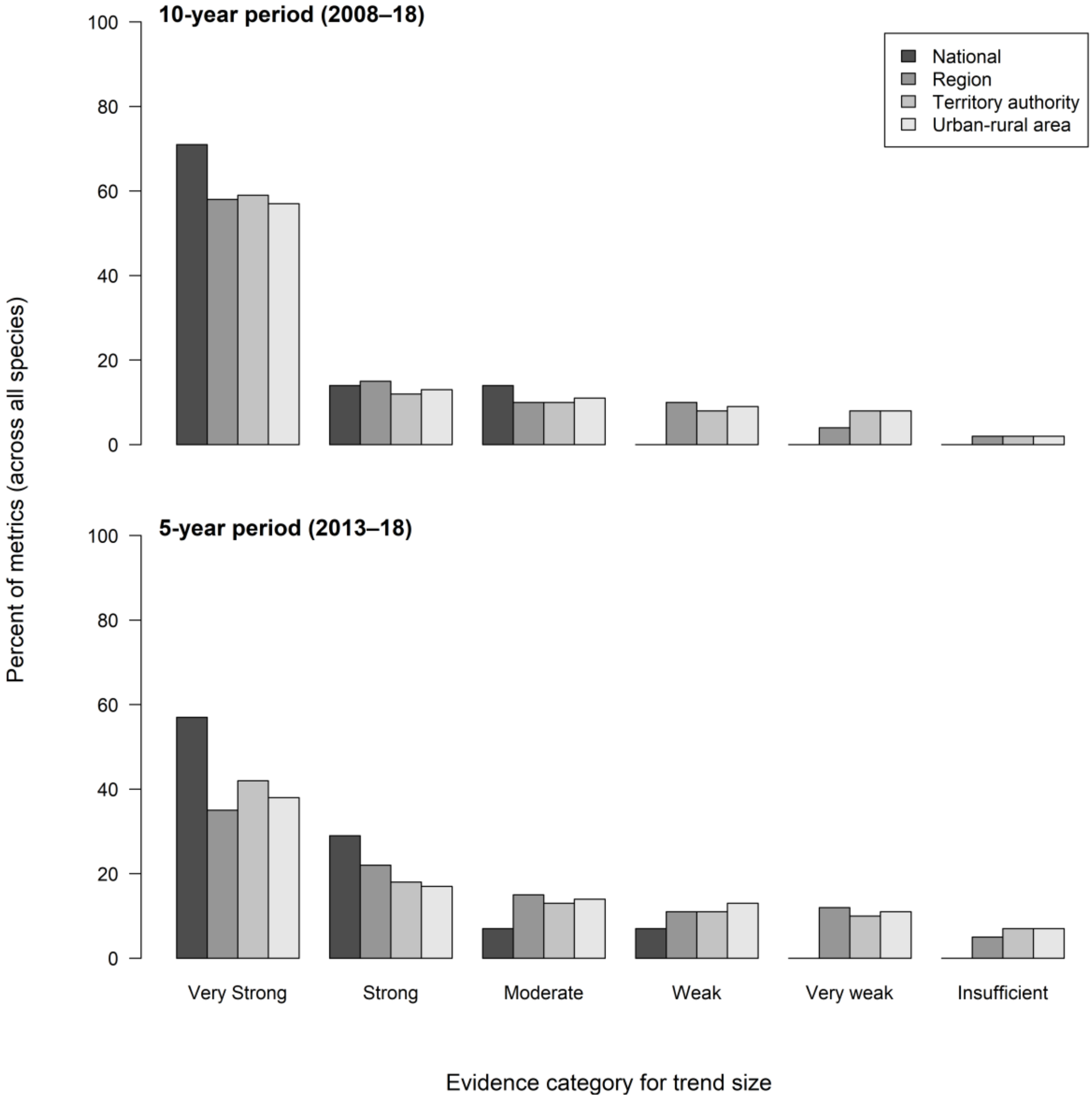

Figure 9. Evidence categories for trend size classification across all species for each spatial scale and period.

5 Discussion and conclusions

The NZGBS is a nationally significant data set (Spurr 2012) as it is the only coordinated programme providing bird count data for multiple species for 12 consecutive years in the urban and rural landscapes nationally. Recently we have developed standardised and automated protocols for cost-effectively editing these data for 16 bird species (Howard et al. 2017; MacLeod et al. 2017, 2018; MacLeod 2019). This protocol could be adapted to facilitate similar improvements for a wider range of species.

The trend analysis and interpretation protocol outlined in this report builds on earlier work exploring how recent advances in statistical modelling techniques could be used to cost-effectively calculate consistent and robust metrics at multiple spatial scales (MacLeod et al. 2015; MacLeod, Howard, Green et al. 2019). Key improvements include:

- better accounting for:
  - variation in garden composition, bird-feeding activities and trends at four spatial scales (national, regional, territorial authority and urban rural area), as well as uncertainties in trend estimates
  - the NZGBS's unbalanced sampling design (i.e. correcting for spatial and temporal variation in sampling effort by weighting estimates according to the actual number of gardens within different neighbourhoods across the country)
- reporting the percentage change in bird counts for any given period and spatial scale, as this metric is easier to communicate and for people to understand than the slope estimates derived from the models (the metrics previously considered; MacLeod et al. 2015)
- helping the user more readily understand and interpret the results – the percentage change estimates (and their respective confidence intervals) are classified in relation to a specified set of alert thresholds relevant to management, and these alert thresholds are adjusted so that they are comparable across the two periods considered.

These improvements have allowed us to:

- deliver an accurate, powerful and robust framework for data analysis that maximises statistical power (and hence the inferences that can robustly be made) while accounting for data noise, which has increased the precision of the metrics and the likelihood of detecting changes in bird counts that would otherwise be missed (MacLeod et al. 2015)
- distinguish between short- and long-term changes in garden bird counts within time frames and at spatial scales relevant to management (e.g. which has the potential to show the impacts of landscape-scale management initiatives) – these garden bird counts include native species that government agencies have responsibility for, and also include introduced species that can signal changes in the health of the environment that otherwise might be missed
- produce comparable metrics in a cost-effective manner to inform management at different scales (national, regional, local), although the weaker evidence

categories for local scales highlight the need to both sustain the annual survey rate and increase local participation rates in the survey to ensure the NZGBS can better inform local conservation efforts.

6 Recommendations

- Future NZGBS campaigns should aim to increase and retain participation in order to increase the accuracy of trends measured at local scales where community groups and local authorities want to use the results to inform their management actions (MacLeod & Spurr 2019). Initiatives that could detract from survey participation should not be pursued.
- Improve the data editing process to set rules for flagging unusual counts for all species (rather than just a subset of species, as currently done) and store this information on the online Datastore.
- Focus future analyses on the fixed time frames (10-year and 5-year periods) to ensure the trend results are comparable across years. This could be expanded in the future to include longer-term trends (e.g. 15-year and 25-year periods).
- Investigate issues flagged for model fit and bootstrapping (in particular for grey warbler and welcome swallow).
- Invite a panel review so that priorities for future developments can be identified and current data editing, analysis and interpretation protocols can be established as a standard.
- Future developments should consider adding new covariates to the base models to better account for variance in counts among spatial units. Candidate covariates for each urban rural area (or, if feasible, garden) could include measures of local landcover matrix (e.g. sourced from the Landcover Database) and predator control activities (e.g. distance to nearest sanctuary). In recent years, NZGBS participants have provided more detailed information on bird-feeding activities as well as the size and composition of survey areas; base models for the relevant periods should be adapted to include these covariates and investigate their influence on bird counts.

7 References

Baillie SR, Rehfisch MM eds. 2006. National and site-based alert systems for UK birds. BTO Research Report No. 226. Thetford, UK, British Trust for Ornithology.

Bates D, Maechler M, Bolker B, Walker S 2015. Fitting linear mixed-effects models using LME4. Journal of Statistical Software 67: 1–48.

Eaton MA, Aebischer NJ, Brown AF, Hearn RD, Lock L, Musgrove AJ, Noble DG, Stroud DA, Gregory RD 2015. Birds of conservation concern 4: the population status of birds in the United Kingdom, Channel Islands and Isle of Man. British Birds. 108: 708–746.

Harrison XA 2014. Using observation-level random effects to model overdispersion in count data in ecology and evolution. PeerJ 2: e616. doi:10.7717/peerj.616.

Howard S, MacLeod CJ, Spurr EB 2017. NZGBS 2007–2015: data editing protocol [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2007-2015-data-editing-protocol

MacLeod CJ 2019. NZGBS 2018: data editing protocol [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2018-data-editing-protocol

MacLeod CJ, Brandt AJ, Spurr EB 2017. NZGBS 2016: data editing protocol [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2016-data-editing-protocol

MacLeod CJ, Brandt AJ, Spurr EB 2018. NZGBS 2017: data editing protocol [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2017-data-editing-protocol

MacLeod CJ, Green P, Gormley AM, Spurr EB 2015. Use of NZ Garden Bird Survey data in environmental reporting: preliminary models to account for spatial variation in sampling effort. Wellington, Ministry for the Environment. http://www.mfe.govt.nz/publications/environmental-reporting/use-nz-garden-bird-survey-data-environmental-reporting

MacLeod CJ, Howard S, Gormley AM, Spurr EB 2019. State of NZ Garden Birds 2018 | Te Āhua o ngā Manu o te Kāri i Aotearoa. Lincoln, Manaaki Whenua – Landcare Research. https://datastore.landcareresearch.co.nz/dataset/state-of-nz-garden-birds-2018

MacLeod CJ, Howard S, Green P, Gormley AM, Brandt AJ, Scott K, Spurr EB 2019. NZ Garden Bird Survey 2017: data editing, analysis, interpretation, visualisation and communication methods. Manaaki Whenua – Landcare Research Contract Report LC3461. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2017-trend-analysis-and-reporting

MacLeod CJ, Spurr EB 2019. NZ Garden Bird Survey 2018: spatial coverage and trends in garden records. Manaaki Whenua – Landcare Research Contract Report LC3470. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2018-participation-trends

R Core Team 2019. R: a language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing. https://www.R-project.org/

Spurr EB 2012. New Zealand Garden Bird Survey – analysis of the first four years. New Zealand Journal of Ecology 36: 287–299.

Spurr EB 2018. NZGBS edited data: 2007-2015 [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2007-2015-raw-data

Spurr EB, Herran M, Watts M, MacLeod CJ 2018a. NZ Garden Bird Survey 2016: raw data [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2016-raw-data

Spurr EB, Herran M, Watts M, MacLeod CJ 2018b. NZ Garden Bird Survey 2017: raw data [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2017-raw-data

Spurr EB, Herran M, Watts M, MacLeod CJ 2019. NZ Garden Bird Survey 2018: raw data [restricted access]. https://datastore.landcareresearch.co.nz/dataset/nzgbs-2018-raw-data