Recording birds in real time: a convenient method for frequent bird recording

Jon J. Sullivan

Department of Ecology, PO Box 84, Lincoln University, Lincoln 7647, New Zealand (Email: tabebuia@alumni.upenn.edu)

Abstract: To make sense of how nature is responding to an increasingly rapidly changing world, a lot of species distribution and abundance data are needed. To infer population trends, these data ideally need to be collected in a standardised, repeatable manner that includes 'absence' data on species sought for but not found. If many people, even just professional ecologists and postgraduate students, are to record biodiversity frequently in their daily lives, a convenient method that meets these requirements is needed. A method is presented here that has been employed by the author since 2003 to frequently record a predefined subset of bird species along standard routes and locations. The approach is a hybrid of the five-minute bird count and slow-walk transect methods, designed for high frequency use while the observer is stationary and moving respectively. Predetermined subsets of bird species are recorded in 20-min intervals, often consecutively, each with one nested 5-min interval. *N*-mixture models now allow for abundance and detection probability to be statistically separated from such simple high frequency, pseudo-replicated count data. Nearly 100 000 bird counts have been collected using this method, plus many more 'sought but not found' records. The value of this simple, high frequency monitoring approach is demonstrated by summarising data from one location, one weekly route, and one daily route for three widespread native forest birds. These show striking patterns of seasonality and biotope use in urban and rural Christchurch. Hence this approach, if widely adopted, could provide a valuable resource for bird monitoring.

Keywords: 5MBC; bellbird (*Anthornis melanura*); bird ecology; citizen science; fantail (*Rhipidura fuliginosa*); grey warbler (*Gerygone igata*); habitat use; monitoring; restoration; reconciliation

Introduction

In addition to formal bird monitoring programmes (usually with tightly defined methods), there is a huge potential for gathering casual observations from many people and in many places. The annual Garden Bird Survey (Spurr 2012) is one successful attempt at tapping into this potential in New Zealand. The advent of the New Zealand portal of eBird (www.ebird. org/nz; Scofield et al. 2012) and the New Zealand Biodiversity Recording Network (NZBRN; www.nzbrn.org.nz) now allow for increasingly easy collation and public sharing of casual (and formal) bird data. Smartphones can now put databases of NZBRN and eBird format into people's hands wherever they go, making it possible for people to record and share every individual they see of some species. The crowd-sourcing philosophy behind such approaches is that useful patterns will emerge from vast amounts of presence-only data collected in eclectic, unstructured ways (Snäll et al. 2011; Marris 2010).

For New Zealand ecologists and ornithologists, there is a useful middle ground to explore between current formal bird monitoring programmes (Spurr 2005) and emerging ad hoc public observations. To be widely used, such structured casual data need to be quick and easy to collect within people's existing activities. To be as useful as possible, they also need to be repeatable, consistent in the species recorded so it is known when and where species are not observed, and collected in standardised ways to facilitate comparisons. Such observations can be made by a wide range of interested bird-literate people with nominal effort, and individuals have used such methods to amass large datasets on local bird populations (Gill 1977; Gibb 2000a, b; Brockie et al. 2009).

An impediment to using simple count data is the difficulty separating detection probability from abundance. This has led some to reject any usefulness of simple indices of population size (Anderson 2001), a position reviewed and countered by Johnson (2008). A variety of more intensive sampling methods, such as capture–recapture and distance sampling, are now commonly used by formal bird surveys because they can directly estimate abundance and detection probability (Ralph & Scott 1981; Kissling & Garton 2006). However, Royle's (2004) binomial *N*-mixture model and its extensions (Kéry 2008; Joseph et al. 2009; Chandler et al. 2011; Dail & Madsen 2011) allow estimation of overall abundance and detection probability from spatially and temporally replicated simple count data. Royle's (2004) original model assumes a closed population but this assumption can be tested, and a modified method adequately models open populations (Dail & Madsen 2011). Effects of covariates can be modelled separately for

their effects on abundance and detection probability (Kéry 2008). These methods greatly increase the utility of spatially and temporally (pseudo-)replicated datasets of simple count data and benefit from high frequency site recording.

The long-standing method for recording comparative bird abundance data in New Zealand is the five-minute bird count (5MBC; Dawson & Bull 1975; Hartley 2012). While its modern form can include distance sampling, in many ways the non-distance original 5MBC method meets the requirements for a simple, standardised method. Five minutes is a practical interval for a point count; it is straightforward, with practice, to stop for 5 min in one place and estimate the numbers present for all bird species seen and heard. However, while such counts are typically well separated in time and space in sampling designs, to avoid recounting the same individuals (Spurr 2005), high frequency pseudo-replicated count data can be useful; they allow for easier separation of detection probability from abundance (Royle 2004) and can better document daily and seasonal activity patterns (Gibb 2000b). Five minutes is insufficiently brief for describing population changes in rare species; monitoring uncommon, mobile birds, requires high replication of five-minute counts (Spurr 2005) and/or longer-duration sampling.

Another common method in New Zealand for monitoring bird populations is the slow-walk transect (O'Donnell 1996; Handford 2002; Spurr 2005; Morgan et al. 2012). While studies have varied in the length and width of transects, these collect simple count data while the observer walks at a slow pace; the emphasis has been on a slow pace to ensure a high detection probability. However, faster movement will only lower the detection probability, not the abundance of resident birds, and so data from the same transect recorded at different mixed speeds should still be comparable using an *N*-mixture approach with travel speed as a covariate of detection probability.

The stationary and mobile methods described here are a balance between convenience and quality. The 5MBC and standard walk line-transect methods are generally conformed to, but with several important exceptions: (1) only predefined selections of bird species, always including all 'prehuman' (present before human settlement) native terrestrial species (i.e. excluding recent immigrants from Australia), are recorded; (2) 20-min intervals are recorded, recording the first five minutes separately for comparison with 5MBC data; (3) mobile data are recorded at a variety of speeds, from walking to driving. These modifications allow birds to be counted in a standardised way under most circumstances, allowing quantification of infrequent observations of uncommon species (such as prehuman native terrestrial birds in Christchurch), and estimate and compare abundances of these species across sites and seasons. By applying these methods to regularly visited sites and routes, a large amount of simple count data have been amassed with little effort. In this paper I present this approach as a useful middle ground between more formal methods and the ad hoc methods implicitly encouraged by NZBRN and eBird (aside from eBird's all-species 'effort-based' recording).

Methods

Birds were monitored in the wider Christchurch area in New Zealand from 2003, with the aim to detect population trends in readily identifiable species along a suburban–rural cycling route from south-western Christchurch to Lincoln. This was extended to more sites and routes in 2008, with the primary aim of quantifying seasonality and habitat use in this area by prehuman forest bird species. Even the most adaptable of these forest birds (fantail *Rhipidura fuliginosa*, grey warbler *Gerygone igata* and bellbird *Anthornis melanura*) are infrequently encountered in this area; hence a spatially and temporally sparse network of 5MBC stations would rarely detect them. Recording presence-only observations when and where species were encountered would have made it difficult and imprecise to make inferences about phenology and habitat use; a method was needed that also logs where and when observations were made but species not found. The 5MBC and line-transect methods, for monitoring over extended periods, were thus adapted to meet these needs. Three standard sets of bird species were recorded, the smallest of which comprises just the prehuman forest bird species (the other sets were these birds plus all birds larger than starlings, and all birds). Set choice was predetermined before site visits, dependent on what other activities are being undertaken. The bird-counting protocols of the 5MBC were otherwise adopted, to make counts repeatable, while accepting that detection probability would be much less than one for some species at some sites.

Birds were counted at a defined number of standard routes and places regularly revisited as part of a normal routine. As such they are not part of a randomised sampling design; hence, the collection of meaningful covariates was important for making inferences. However, one weekly run route was designed as a transect from the Cashmere Hills (Christchurch) onto the adjacent plains, passing through all local patches of forest containing native woody vegetation (see below). In addition, three different ride routes were undertaken to give replication for assessing the Christchurch suburban–rural gradient. Birds were counted for the duration of each visit/ route whenever observations were possible.

There are several advantages of an approach such as this: (1) observations of infrequently encountered species can readily be put into a quantitative context; (2) data from frequent re-sampling across many sites allow the estimation of detection probabilities and abundances using Royle's (2004) method (data can also always be subsampled later to reduce covariation, if required); (3) frequent resampling allows the effects of time of day and weather to be described, and the seasonal timing of species movements and activities to be documented (which is of increasing interest as species are expected to respond to the increasingly rapidly changing global climate; van Bunnik 2007, p. 356); and (4) low-intensity observing whenever standard sites are visited is an easy habit to adopt. In addition, field entry of data into a smartphone linked to a database largely negates the effort of data entry and management.

Stationary method

The stationary method, used since 2008, is essentially a 5MBC (Dawson & Bull 1975) extended to 20 min. This makes it practical to record consecutive intervals when at a site (or travelling through a site) for several hours. Such long stretches of recording are helpful for obtaining counts and observation probabilities for rarely encountered species, with it being prohibitively disruptive to continuously record at 5-min intervals. From March 2010, the birds observed within the first five minutes of each 20-min interval were separately recorded to give a subset of data comparable with 5MBC data.

The minimum and maximum number of individuals seen in an interval were recorded for each bird species, with all individuals that enter the sampling area (including individuals that may re-enter after leaving) being noted. The minimum

count is the maximum number of individuals seen at one time (the method used by the annual Garden Bird Survey; Spurr 2012) plus any unambiguous additional individuals. For example, if a pair of blackbirds and later two males were observed the minimum would be three, unless the pair flew off in one direction and the two males arrived soon afterwards from another direction, in which case the minimum count would be four (this best judgement is also used in 5MBC; Dawson & Bull 1975). A maximum count can also be calculated by assuming that every individual that enters the sampling area is new. For birds heard but not seen, full song, calls, and wing beats (especially distinctive with kererū *Hemiphaga novaeseelandiae*) are noted separately; the minimum number of individuals in this case is the number of locations from which sound comes at the same time, with the exception that if two birds are clearly counter-singing from two locations, these are also recorded as two individuals even if they both do not sing simultaneously (as in 5MBC). As with sighted birds, if two birds sing at different times from clearly different locations without a bird being observed to fly between them, they are regarded as separate individuals. Counts of birds flying by are separated from 'resident' birds (birds that land at the site) since, unlike resident bird counts, the number of birds flying should linearly scale with survey duration.

For both seen and heard birds, those observations made with complete confidence are noted as such; glimpses of birds or snippets of song are recorded separately and flagged as uncertain. Observations of birds seen and heard within 80 m are also separated from those further away. This distance is arbitrary, based on the distance to a selection of prominent fences and shelter belts in farm fields on a frequently cycled route; it is also a relevant cut-off for identifying and counting birds the size of starlings and larger without binoculars (NB in urban and forest environments, birds cannot normally be seen on the ground 80 m away). Moving birds seen both within and further than 80 m are only recorded within 80 m. To remain consistent with a common approach to 5MBC, any birds seen or heard more than 200 m away are ignored (or added anecdotally).

Mobile method

The line-transect method differs from the stationary method in that double counting of individuals is rarely an issue (especially when the observer is travelling faster than a walk; Gregory et al. 2004). This makes the mobile method easier to carry out than the stationary method. The same 5MBC-based counting method and distance classes from the stationary method are used for counts made while walking, running, biking, and as a front passenger in a car or bus. As in distance sampling, counts are recorded in groups, where any bird within 20 m of another is defined as part of the same group. This allows the separation of one large flock at one place along a route section from many scattered individuals. When travelling through a contiguous biotope (e.g. along a forest track), the observer records data in 20-min intervals. Otherwise, routes are split by obvious landmarks (e.g. road intersections) separating areas of broadly different biotope. The lengths of these sections vary markedly (hundreds of metres to a few kilometres) as their creation is been primarily determined by convenience, repeatability, and the speed at which the observer is moving.

The mobile method has been employed since March 2003 to count all prehuman native birds, all birds the size of starlings or larger, and all road-kill, along a 17-km cycling route from Christchurch to Lincoln (Fig. 1). It has also been applied to
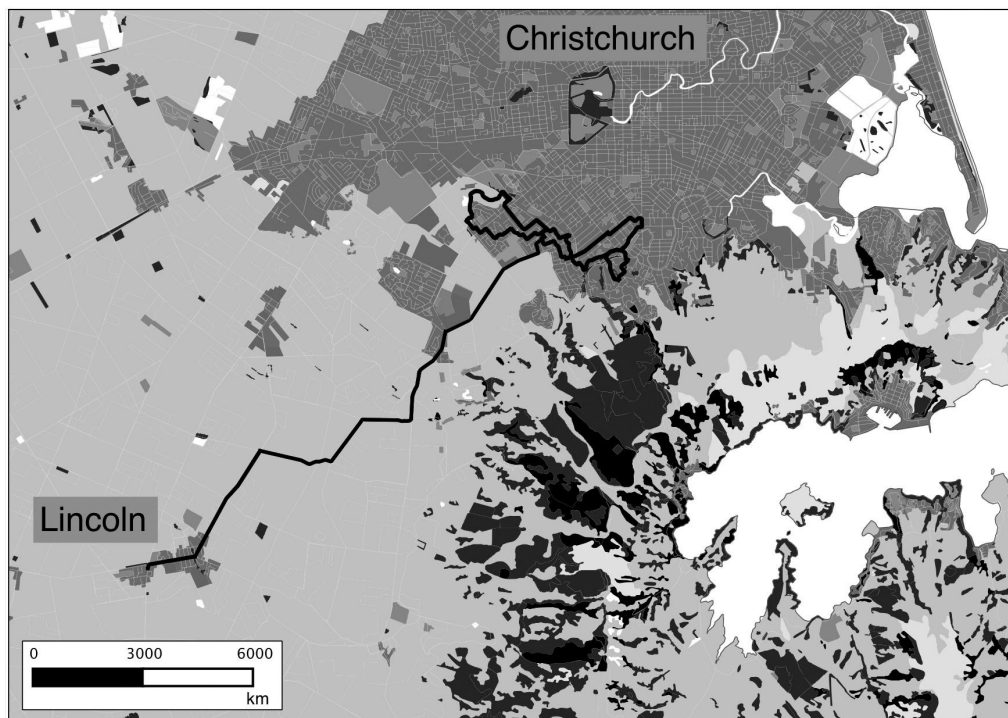

Figure 1. The Christchurch area showing the run route (black 'figure of eight' in the centre), garden site (the centre of the 'figure of eight'), and bike route (black line from centre to Lincoln). The landscape is shaded combining categories from the New Zealand Landcover Database 2 (2002), updated to include subsequent suburban developments in south-western Christchurch and Lincoln. Light greys are high and low production pasture and cropping land. Mid-greys are built-up land and open parkland (the latter is the lighter shade). Dark greys are woody cover, including exotic plantation forestry, shelterbelts, and deciduous woodlands, with indigenous forest separated as black. White areas are other categories (e.g. rivers, gravel mines).

a standard run route since July 2008 (Fig. 1), initially just to prehuman forest bird species and later to the same suite of birds as recorded on the cycle route. The eastern and western halves of this 25.4-km route are alternated weekly; the route was created to compare areas of housing and open parkland with areas of native planting.

Line transects work particularly well for counting conspicuous, low density species in open habitats (Gregory et al. 2004). This matches the counts of large birds through the open pastoral farmland between Christchurch and Lincoln. The detection probability for non-vocalising, non-flying individuals undoubtedly decreases markedly in areas of housing and forest cover, underscoring the importance of choosing route sections that separate areas of dissimilar visibility and revisiting those routes with high frequency.

Notation and technology

Except for cycle routes (when pen and paper are used), data are entered directly in the field using an iPod Touch or iPhone (using the TapForms database application). Data are stored in a desktop FileMaker Pro database built on the field structure of the New Zealand Biodiversity Recording Network (available as the NZBRN spreadsheet template for birds at http://www. nzbrn.org.nz). The convenience of this method hinges on simple, rapid data entry in the field using a shorthand notation; species are identified by unique short abbreviations linked with full names in the database.

In the stationary method, all observations of individual(s) of a species that enter a site are recorded, adding '~' for approximate counts (e.g. for a large flock of starlings flying by), '!' for individuals clearly not previously recorded, '@' for individuals clearly previously recorded, 'f' for birds flying by, 'vs' for birds heard vocalising before seen and 'sv' for birds seen before heard vocalising, '+' before a count for individual(s) beyond 80 m, '++' before a count for individual(s) beyond 200 m (not consistently recorded), '&' when a group of individuals is joined by more individuals, and '-' when individuals leave a group. '|' is used to divide counts from the first five minutes and subsequently. '+' is used between parents and young offspring with the count of young followed by a 'y' (e.g. 'PD 2+6y' is a pair of paradise shelducks with six young, while just 'PD 2+6' would mean a group of eight paradise shelducks, each within 20 m of another, with six beyond 80 m). Any comments follow in parentheses. A typical example is 'Bbg|1f', which the database translates to mean one black-backed gull seen flying by after the first five minutes within 80 m. A more elaborate example is 'Blkb 1,1! |2!,1,1@,2&2!', the database translates this as a minimum of six and maximum of nine blackbirds seen within 80 m, none seen further than 80 m, with exactly two birds seen in the first five minutes both within 80 m, and with none flying by. Birds heard and not seen are entered as a separate line beginning with, for example, 'Blkb song' or 'Blkb call', depending on the vocalisation. Uncertain identifications are also entered on another line, with a '?' following the species code (e.g. 'Blkb?').

The mobile method notation is equivalent except that there is (rarely) any ambiguity in double counting, so '!' is not used after every count of a clearly new individual but rather it is assumed that each count represents new individuals unless followed by an '@'. This shorthand is designed to be fast to enter while still being data rich. It is simple to use, with practice, and allows for a range of subsequent interpretations of the counts.

Monitoring at selected standard places and routes

Results from three standard places/routes are presented below to illustrate the strengths and limitations of this methodology (a full analysis of the dataset is beyond the scope of this paper). In the summary of my results presented, cycle and run route sections are divided by broad land-use type; for the cycle route, these are Christchurch city, farmland, and Lincoln town. The weekly run route is separated into sections of urban housing/playing fields and forest-like biotopes, with the latter defined as those areas with more than 0.25 ha of contiguous canopy or subcanopy of evergreen woody species (Ernle Clark Reserve, Ashgrove Reserve, Purau Reserve, the native plantings along the walkway through Centennial Park, the native plantings along the Heathcote River between Curletts Road and Templetons Road, and the walkway between Valley Road and Macmillan Ave; together these forest-like areas account for 2.5 km (10%) of the 25.4-km run route).

Since March 2007, every prehuman forest bird seen or heard from a single garden site (the author's home) in Hoon Hay, Christchurch, has been noted. The site (−43.562°E 172.604°N WG84) is surrounded on all sides by New Zealand's bungalow-style suburbia and English-settler-inspired open parkland. This has been augmented by stationary 20-min-interval sampling since September 2008.

Analysis

Birds counted per 20-min interval for stationary counts, and birds counted per kilometre for mobile counts, are modelled in R (R Development Core Team 2011) using the Generalized Least Squares (GLS) function from the nlme package (Pinheiro et al. 2011). Autoregressive autocorrelation was accounted for using corARMA(p=1). As GLS cannot model Poisson error distributions, count data were log+0.1-transformed, and GLS results compared to equivalent Poisson GLMs without autocorrelation. Only those results that were significant in both models are conservatively reported.

Abundances and detection probabilities in the count data are estimated using Dail and Madsen's (2011) method for open populations, using the function pcountOpen in the R package unmarked (Fiske & Chandler 2011), using a Poisson distribution. This provides estimates for a population's initial abundance, recruitment, survival, and detection probability. This method was designed for point-count data rather than variable-length transect-count data. Conceptually, the approaches are similar, with each transect representing a different group of points. The abundance in each route section is offset by (1*log(distance)) to account for the lengths of the route sections. pcountOpen performed equally well at estimating the true abundance parameters and detection probability of sets of simulated count and transect data (unpubl. data). However, pcountOpen models with many explanatory variables take many hours to days to estimate parameters with maximum likelihoods, so only simple models of the explanatory variables of greatest interest (biotope and season) are presented here. The estimated detection probabilities and (for brevity) just the mean estimates of total abundance are provided (which average the population abundance estimates from each sample date as calculated from the estimated initial abundance, recruitment, and survival parameters).

Results

The main strength of the methodology presented is the high spatial and temporal (pseudo-)replication made possible by easy, repeated counts of a manageable list of bird species. Between March 2003 and 1 May 2011, 91 824 birds have been counted in this way, 80% since 2008. Included in this are 62 240 counts (including 789 road-kill birds) from 712 cycle rides between Christchurch and Lincoln, and 7399 bird counts from 54 complete circuits of the run route. While these numbers do not mean anything in themselves, they illustrate the ease with which large amounts of data can be accumulated by individuals as part of their daily lives. The data also show some striking seasonal and annual changes, some of which are summarised here as an illustration of the use of this approach.

Garden-site example: seasonality of backyard native forest birds

The counts from the suburban Christchurch garden site document an annual pattern of seasonality in visits by the three prehuman native forest bird species present (fantail *Rhipidura fuliginosa*, grey warbler *Gerygone igata*, and bellbird *Anthornis melanura*; Fig. 2). These species have never been observed in spring and grey warblers also never in winter, consistent across four consecutive years (from March 2007 to May 2011, with 652 predetermined observation intervals since September 2008; Fig. 2). GLS models of the predetermined data, accounting for autocorrelation, confirmed a significant seasonal effect and no significant year effect for each species (season effect for fantails $F_{3,647} = 5.9$, $P < 0.01$; grey warblers $F_{3,647} = 8.8$, $P < 0.01$; bellbirds $F_{3,647} = 2.2$, $P = 0.08$). These patterns must be interpreted with caution since more than one bird at a time was rarely observed, and undoubtedly the same individuals were counted on multiple occasions (the pattern observed, while broadly consistent across years, could be due to the activities of very few individuals).

In the 215 20-min intervals since the first five minutes were separately recorded, only 11 individuals of prehuman forest bird species were seen or heard, only one of which was observed in the first five minutes. This is because these birds are not only infrequent but also typically brief visitors to the garden site (despite its increasingly thick and diverse native woody cover). Repeated bouts of continuous observations clearly record more of these rare visits than intermittent short counts; a single 5MBC per month would likely have recorded none of these species at the site over this period.

Run-route example: seasonality and habitat use by native forest birds in suburban Christchurch

Without spatial replication, counts from one site over several years cannot be generalised to the wider landscape. The standard run route was designed to assess the seasonal and spatial (biotope) use of suburban Christchurch by prehuman forest bird species. These show that the garden site counts are not unusual for houses and gardens in south-western Christchurch, both in the infrequent observations of such birds and their near-absence in spring (Fig. 3). However, all three bird species (fantail, bellbird and grey warbler) show a striking preference for the few areas of dense, evergreen (and typically native) forest-like woody vegetation (Fig. 3).

Counts of all species were significantly greater in forest-like biotopes than in suburban houses, gardens, and playing fields (GLS of count per kilometre: fantail biotopes $F_{1,919} = 230$, $P < 0.01$, seasons $F_{3,919} = 2.7$, $P < 0.05$; grey warbler biotopes $F_{1,919} = 97$, $P < 0.01$, seasons $F_{3,919} = 4.6$, $P < 0.01$; bellbird biotopes $F_{3,919} = 9.5$, $P < 0.01$, seasons $F_{1,919} = 19$, $P < 0.01$). Despite being only 10% of the run route by distance, 83% of the fantail records, 83% of grey warbler records, and 35% of bellbird records were in forest-like biotopes (most of the remainder of the bellbird records were from flowering eucalypt and kōwhai (*Sophora* spp.) trees in the Cashmere Hills).
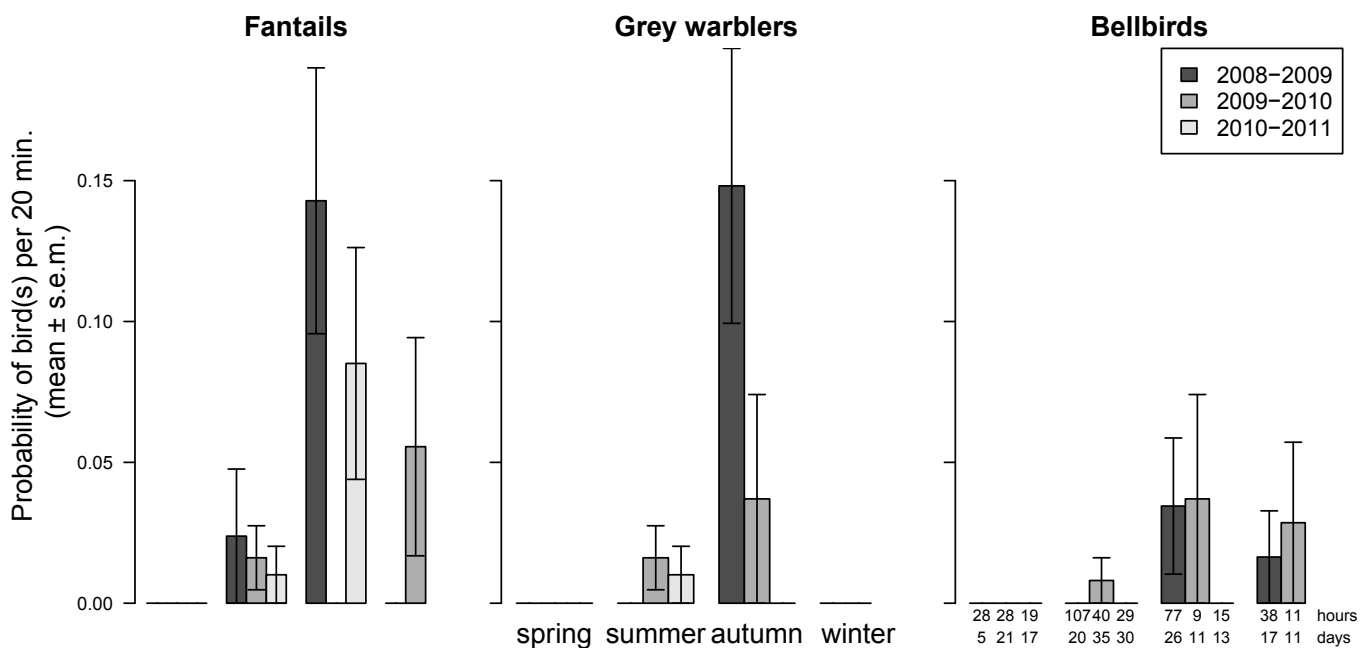

Figure 2. Seasonality in native forest bird sightings at the garden site between March 2007 and November 2010. All were observations of a single bird per 20-min interval with the exception of a group of three fantails seen once and two grey warblers seen once. In the 652 20-min intervals, fantails were counted in only 13 intervals, grey warblers in 9, and bellbirds in 6.
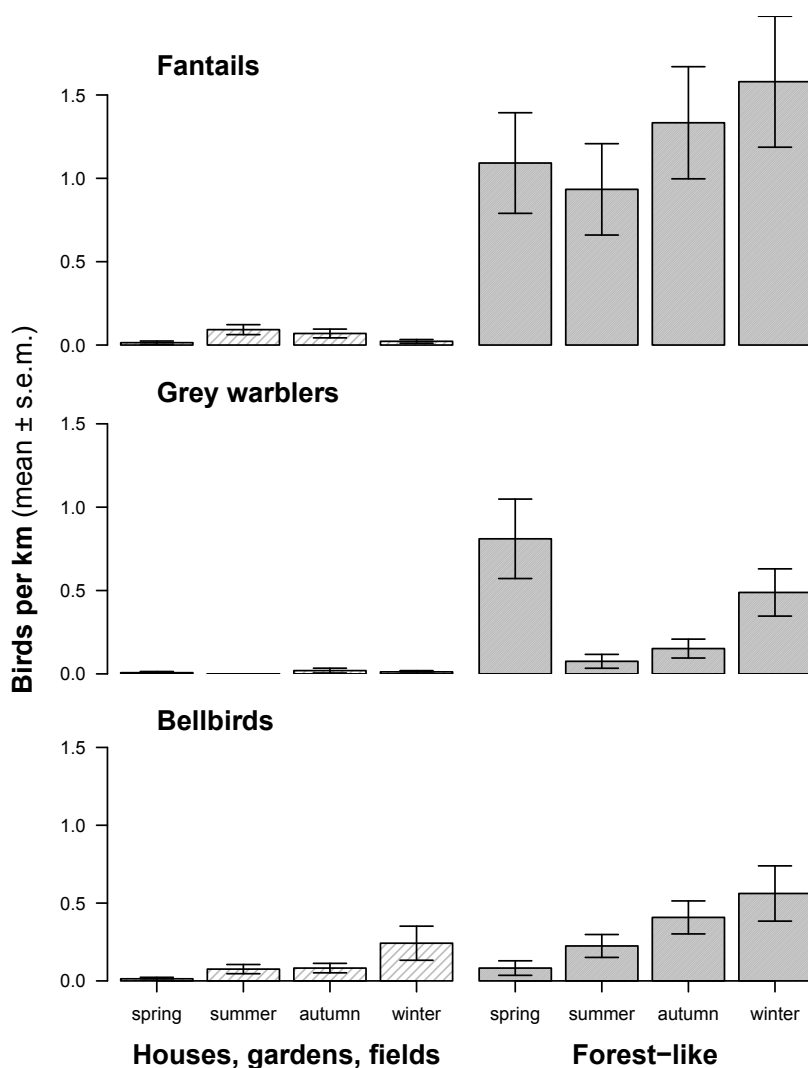
Figure 3. Seasonality and biotope preferences by native forest birds recorded on the run route between July 2008 and November 2010. Forest-like biotopes include more than 0.25 ha of contiguous canopy or subcanopy of evergreen woody species (see Methods).

During the spring these species, especially fantails and grey warblers, were almost entirely confined to forested biotopes, in stark contrast to the housing, gardens (including the garden site above), and fields that dominate the landscape (Fig. 3). Along this route, observations were made in late spring and summer of fantails nesting and successfully fledging chicks in Ernle Clark Reserve and Ashgrove Terrace Reserve, a fantail with three fledglings in the native woody riparian planting along the Heathcote River between Curletts Road and Templetons Road, and a grey warbler nesting along the Macmillan Ave – Valley Road walkway.

N-mixture models of counts as a function of distance and biotope using pcountOpen confirm that the biotope differences in counts were consistent with differences in initial abundance for fantail ($z = -5.17$, $P < 0.01$) and grey warbler ($z = -4.04$, $P < 0.01$), with biotope also affecting the detection probability of grey warbler only (higher in housing than forest, $z = 2.14$, $P < 0.05$). Bellbirds were less frequently counted and there was no detectable difference in initial abundance between biotopes, although there was higher recruitment and lower survival in forest than housing (recruitment $z = -3.27$, $P < 0.05$; survival $z = 3.20$, $P < 0.05$). The detection probability for fantails was estimated at 0.11 (95% CI $0.061 - 0.2$) in forest-like biotope and 0.055 ($0.027 - 0.11$) in suburban houses, gardens, and playing fields. For grey warblers, it was 0.071 ($0.026 - 0.18$) and 0.99 (the near-absence of grey warbler counts in suburban areas gave a zero-to-infinity confidence interval here), respectively, and for bellbirds, 0.26 ($0.13 - 0.45$) and 0.52 ($0.38 - 0.66$). The estimated average abundance of fantails was 6 per kilometre (km) in forest-like biotopes and 1.5 per km in suburban houses, gardens, and playing fields; for grey warblers it was 4.3 per km and 0.03 per km respectively; and for bellbirds, 1.1 per km and 0.55 per km.

Cycle-route example: seasonal patterns of species richness between Christchurch and Lincoln

The cycle transects show patterns of biotope use and seasonality in urban and rural areas (Fig. 4). Fantail and grey warbler counts were greater in farmland than in Christchurch City's suburban housing, and those of fantails lowest in the spring (Fig. 4; GLS of count per kilometre: fantail land use $F_{2,2951} = 6.2$, $P < 0.05$, seasons $F_{3,2951} = 13.6$, $P < 0.01$; grey warbler land use $F_{2,2951} = 11.2$, $P < 0.01$, seasons $F_{3,2951} = 1.74$, $P > 0.05$). Counts of these species also varied significantly among years (GLS: fantail $F_{1,2951} = 38.4$, $P < 0.01$; grey warbler $F_{1,2951} = 18.5$, $P < 0.01$). Bellbird counts were less frequent and varied by year and season, being least common in spring and summer, but did not differ significantly between farmland and areas of housing (GLS: land use $F_{2,2951} = 2.4$, $P > 0.05$.; season $F_{3,2951} = 4.5$, $P < 0.01$; year $F_{1,2951} = 9.1$, $P < 0.01$).
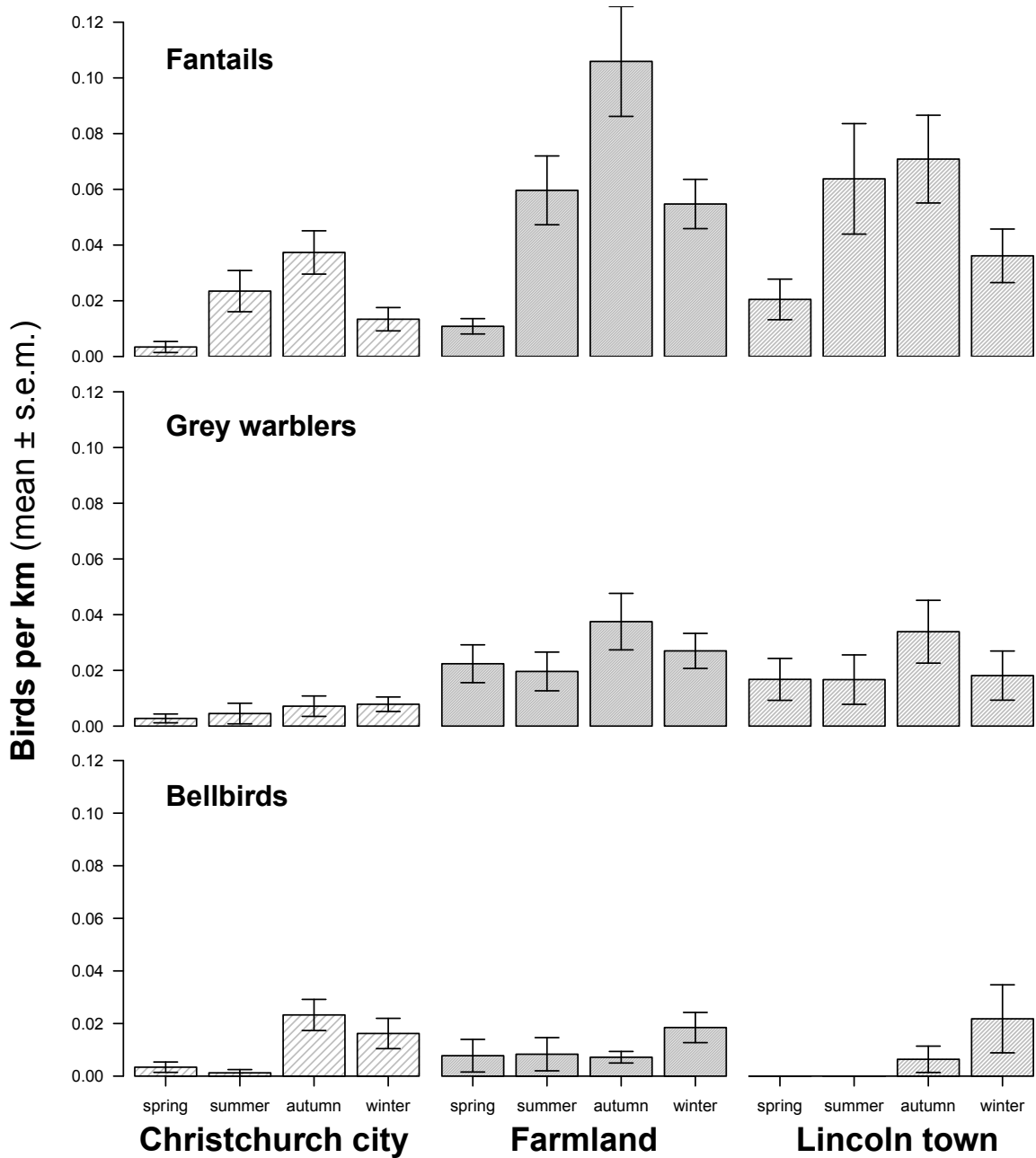
Figure 4. Seasonal patterns of native forest bird counts recorded on the cycle route between March 2003 and November 2010. Fantails and grey warblers were seen and heard most frequently in farmland

These patterns are also consistent with two alternative cycle routes counted monthly since March 2009 (unpubl. data).

N-mixture models using pcountOpen estimated the overall detection probability for fantails as 0.13 (95% CI 0.1 – 0.16), for grey warblers 0.03 (0.021 – 0.043), and for bellbirds 0.076 (0.04 – 0.14). Estimated average abundances across the transect and survey period were 2.1, 3.9 and 0.58 per kilometre for fantails, grey warblers and bellbirds respectively (estimates per route section were not available from pcountOpen).

In total 7 endemic species, 12 non-endemic native species, and 10 naturalised species were observed (from the counts of all birds larger than starlings and all prehuman forest bird species). Additional to these are eight naturalised species and two post-human-settlement native species that were observed along the

route but not routinely recorded except as road-kill. The low number of endemic birds is despite 87% of New Zealand's non-marine bird fauna being endemic (Wilson 2004). The endemic species recorded from this route were (in declining total count): paradise shelduck (*Tadorna variegata*, 1440), grey warbler (138), pied oystercatcher (*Haematopus finschi*, 99), bellbird (84), New Zealand scaup (*Aythya novaeseelandiae*, 8), and kererū (*Hemiphaga novaeseelandiae*, 4). For comparison, the top five most recorded species were blackbirds (*Turdus merula*, 13 110), spur-winged plovers (*Vanellus miles novaehollandiae*, 6691), rock pigeons (*Columba livia*, 5865), black-backed gulls (*Larus dominicanus dominicanus*, 5569), and pūkeko (*Porphyrio porphyrio melanotus*, 3889).

Discussion

The results illustrate the value of making simple, frequently repeated bird counts. Such methods could complement, but certainly should not replace, existing 5MBC sampling networks and distance-sampling monitoring techniques. Focused scientific studies of bird populations clearly benefit from using dedicated methods that produce precise estimates of detection probability and abundance, applied to fully randomised sampling designs. Here it is demonstrated that there can also be value in collecting less structured but more frequent counts of predefined subsets of bird species at frequently revisited sites. The ability to estimate detection probabilities and abundances, with uncertainties, from high frequency count data (Royle 2004) greatly increases the usefulness of simple count data and can negate traditional concerns with using count data as indices of abundance (Johnson 2008).

The methodology presented is habit forming and could be applied by more people in more places and times than other methods that are currently used. It is also arguably a more appropriate method than a spatially and temporally sparse grid of 5MBC stations (Spurr 2005) for monitoring uncommon bird species since it gathers many more observations of these species and the non-independent repeated samples can be used to estimate detection probabilities and abundances (Royle 2004). The method could also plausibly be attractive for community groups involved in restoration since all their observations of their species of interest at their sites of interest could be used, so long as the dates and times when species are not observed are also consistently recorded.

How frequently data should be collected will depend in part on the questions being addressed with monitoring, and also with the anticipated detection probability. As well as gathering more counts of uncommon species, higher frequency recording will result in better abundance estimates from N-mixture models, meaning that higher frequency counts should detect more subtle changes than intermittent counts made across the same number of sites. Questions involving how seasonal changes in bird phenology and activity respond to climate change will also benefit from high frequency recording if the timing of activities shifts by days and weeks among years. This differs from typical bird monitoring programmes in New Zealand and internationally that emphasise repeat surveys made a month or more apart (Spurr 2005).

The results presented here show that fantails and grey warblers in Christchurch City, and bellbirds to a lesser extent, are largely restricted to forest-like biotopes, all with native plantings, and that this effect is strongest in spring. Such a preference for forest was also found in Dunedin, using monthly slow-walk transects (van Heezik et al. 2008), and associations between native forest birds and native forest vegetation have been documented before, for example in native forest versus pine plantations (Clout & Gaze 1984) and by the degree of native woody vegetation in Hamilton gardens (Day 1995). These patterns are consistent with strong habitat selection and suggest that creating more patches of evergreen forest habitats within urban and rural Christchurch (Meurk & Swaffield 2000; Stewart et al. 2004) would greatly benefit populations of native forest birds. They also bring into question the conclusion of Innes et al. (2010, p. 100) that in 'deforested urban and rural landscapes at local and regional scales ... habitat area is frequently a primary limiting factor for all but the most pest-resistant and habitat-generalist forest birds.' The results here suggest that this habitat limitation may also be strong in populations of the most pest-resistant and habitat-generalist

forest birds. Further study is needed to assess the extent to which these patterns are due to habitat-limited populations or small predator-limited populations aggregating in their most preferred habitats.

New Zealand's wreckage of a bird fauna (Diamond 1984; Innes et al. 2010) is particularly amenable to high frequency, low intensity monitoring, since there are relative few common and widespread terrestrial species (Brockie 1997). In most cases, especially around cities and towns, unambiguous identifications are possible even when a bird is seen briefly. This makes higher speed recording on transects practical (e.g. Westland naturalist Mark Crompton has made many thousands of bird observations from a car and entered them into www.nzbrn.org. nz). Doing this in countries with larger urban and rural bird faunas would require more expertise and be more difficult, perhaps impractical. When applying N-mixture models to count data, traditional slow-walk transect methods can be augmented with observations made at higher speeds since travel speed will affect detection probability only. The results presented here support this, with the cycle route abundance estimates of fantails, grey warblers, and bellbirds falling between the run-route suburban and forest-like biotope estimates. This is despite travelling at least five times faster on the cycle route, reflected in lower estimated detection probabilities.

New Zealand, like the rest of the world, is undergoing environmental changes of unprecedented magnitude and diversity, including changes in land use, climate, nutrient cycling, and regional species pools (Taylor et al. 1997; van Bunnik et al. 2007). Making sense of how nature responds to these requires a lot of long-term, high frequency, widespread monitoring data (Wiens 2009). New Zealand has been traditionally poor, both institutionally and culturally, at supporting such monitoring programmes (Spurr 2005; Kelly & Sullivan 2010), with an important exception being the Bird Atlas of the Ornithological Society of New Zealand (Bull et al. 1985; Robertson et al. 2007). The challenge facing eBird NZ and NZBRN is to connect together bio-literate members of communities across the country. I suggest that it is a responsibility of professional ecologists and their students to take the lead. Our knowledge of the spatial and temporal changes in New Zealand birds could be greatly increased if more individuals repeatedly recorded a convenient set of species at a convenient set of personal sites or routes, using a simple yet structured method and with data shared via websites like NZBRN and eBird.

Acknowledgements

References

Anderson DR 2001. The need to get the basics right in wildlife field studies. Wildlife Society Bulletin 29: 1294–1297.
Brockie B 1997. City nature. A guide to the plants & animals of New Zealand cities and towns. Auckland, Viking. 102 p.

Brockie RE, Sadleir RMFS, Linklater WL 2009. Long-term wildlife road-kill counts in New Zealand. New Zealand Journal of Zoology 36: 123–134.

Bull PC, Gaze PD, Robertson CJR 1985. The atlas of bird distribution in New Zealand. Wellington North, The Ornithological Society of New Zealand. 296 p.

Chandler RB, Royle JA, King DI 2011. Inference about density and temporary emigration in unmarked populations. Ecology 92: 1429–1435.

Clout MN, Gaze PD 1984. Effects of plantation forestry on birds in New Zealand. Journal of Applied Ecology 21: 795–815.

Dail D, Madsen L 2011. Models for estimating abundance from repeated counts of an open metapopulation. Biometrics 67: 577–587.

Dawson DG, Bull PC 1975. Counting birds in New Zealand forests. Notornis 22: 101–109.

Day TD 1995. Bird species composition and abundance in relation to native plants in urban gardens, Hamilton, New Zealand. Notornis 42: 175–186.

Diamond JM 1984. Distributions of New Zealand birds on real and virtual islands. New Zealand Journal of Ecology 7: 37–55.

Fiske I, Chandler R 2011. unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43: 1–23. http://www.jstatsoft.org/v43/i10/.

Gibb JA 2000a. Activity of birds in the Western Hutt Hills, New Zealand. Notornis 47: 13–35.

Gibb JA 2000b. Dawn to dusk counts of common or garden birds, Wellington, New Zealand. Notornis 47: 184–191.

Gill BJ 1977. Counts of birds from a car in the Manawatu. Notornis 24: 75–81.

Gregory RD, Gibbons DW, Donald PF 2004. Bird census and survey techniques. In: Sutherland WJ, Newton I, Green RE, eds., Bird ecology and conservation: a handbook of techniques. Oxford University Press. Pp. 17–56.

Handford PA 2002. Native forest monitoring: a guide for forest owners and managers. Paekakariki, New Zealand, FRONZ.

Hartley L 2012. Five-minute bird counts in New Zealand. New Zealand Journal of Ecology 36: 268–278.

Innes J, Kelly D, Overton JMcC, Gillies C 2010. Predation and other factors currently limiting New Zealand forest birds. New Zealand Journal of Ecology 34: 86–114.

Johnson DH 2008. In defense of indices: the case of bird surveys. Journal of Wildlife Management 72: 857–868.

Joseph LN, Elkin C, Martin TG, Possingham HP 2009. Modeling abundance using N-mixture models: the importance of considering ecological mechanisms. Ecological Applications 19: 631–642.

Kelly D, Sullivan JJ 2010. Life histories, dispersal, invasions, and global change: progress and prospects in New Zealand ecology, 1989–2029. New Zealand Journal of Ecology 34: 207–217.

Kéry M 2008. Estimating abundance from bird counts: binomial mixture models uncover complex covariate relationships. The Auk 125: 336–345.

Kissling ML, Garton EO 2006. Estimating detection probability and density from point-count surveys: a combination of distance and double-observer sampling. The Auk 123: 735–752.

Marris E 2010. Birds flock online. Supercomputer time will help ornithologists make ecological sense of millions of records of bird sightings. Nature News 10 August.

Meurk CD, Swaffield SR 2000. A landscape ecological framework for indigenous regeneration in rural New Zealand-Aotearoa. Landscape and Urban Planning 50: 129–144.

Morgan DKJ, Waas JR, Innes J, Arnold G 2012. Native bird abundance after Australian magpie (*Gymnorhina tibicen*) removal from localised areas of high resource availability. New Zealand Journal of Ecology 36: 333–339.

O'Donnell CFJ 1996. Monitoring mohua (yellowhead) populations in the South Island, New Zealand, 1983–93. New Zealand Journal of Zoology 23: 221–228.

Pinheiro J, Bates D, DebRoy S, Sarkar D, R Development Core Team 2011. nlme: Linear and nonlinear mixed effects models. R package version 3.1-102.

R Development Core Team 2011. R: A language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing. http://www.R-project.org/. ISBN 3-900051-07-0.

Ralph CJ, Scott JM eds 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology 6. Lawrence, KS, The Cooper Ornithological Society and Allen Press. 641 p.

Robertson CJR, Hyvönen P, Fraser MJ, Pickard CR 2007. Atlas of bird distribution in New Zealand 1999–2004. Wellington, The Ornithological Society of New Zealand. 533 p.

Royle JA 2004. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60: 108–115.

Scofield RP, Christie D, Sagar PM, Sullivan B 2012. eBird and avifaunal monitoring by the Ornithological Society of New Zealand. New Zealand Journal of Ecology 36: 279–286.

Snäll T, Kindvall O, Nilsson J, Pärt T 2011. Evaluating citizen-based presence data for bird monitoring. Biological Conservation 144: 804–810.

Spurr EB 2005. Monitoring bird populations in New Zealand: a workshop to assess the feasibility of a national bird population monitoring scheme. Landcare Research Science Series 28, Lincoln, New Zealand. 29 p.

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

Stewart GH, Ignatieva ME, Meurk CD, Earl RD 2004. The re-emergence of indigenous forest in an urban environment, Christchurch, New Zealand. Urban Forestry & Urban Greening 2: 149–158.

Taylor R, Smith I, Cochrane P, Stephenson B, Gibbs N 1997. The state of New Zealand's environment 1997. Wellington, Ministry for the Environment (ME 612) and GP Publications.

van Bunnik A, Pollock A, Somerset E, Francke J, Fyfe J, Preston J, Crosfield J, Porter J, Daw J, Thompson K, Leslie K, Johnston K, Janssen K, Manley L, Stirling L, Kennedy M, MacLeod M-A, Thompson M, Zaman N, Franklin P, Peeters P, Reid R, Perry R, Lewis S, Fitzgerald T, Wilson T, Power V, Studd Z 2007. Environment New Zealand 2007. Wellington, Ministry for the Environment (ME 847). 456 p.

van Heezik Y, Smyth A, Mathieu R 2008. Diversity of native and exotic birds across an urban gradient in a New Zealand city. Landscape and Urban Planning 87: 223–232.

Wiens JA 2009. Is 'monitoring' a dirty word? Bulletin of the British Ecological Society 40: 39–40.

Wilson K-J 2004. Flight of the huia: ecology and conservation of New Zealand's frogs, reptiles, birds and mammals. Christchurch, Canterbury University Press. 411 p.