LANDCARE RESEARCH
MANAAKI WHENUA

Indicator M3: Avian representation

Indicator M3: Avian representation

Catriona MacLeod

Landcare Research

Excerpt from:

Bellingham PJ, Overton JM, Thomson FJ, MacLeod CJ, Holdaway RJ, Wiser SK, Brown M, Gormley AM, Collins D, Latham DM, Bishop C, Rutledge D, Innes J, Warburton B 2016. Standardised terrestrial biodiversity indicators for use by regional councils. Landcare Research Contract Report LC2109.

Prepared for:

Regional Councils' Biodiversity Monitoring Working Group

Auckland Council
Bledisloe Building, Level 2 South
24 Wellesly St
Auckland Central

August 2016

Landcare Research, Gerald Street, PO Box 69040, Lincoln 7640, New Zealand,
Ph +64 3 321 9999, Fax +64 3 321 9998, www.landcareresearch.co.nz

Reviewed by:	Deb Wilson, Landcare Research Philippa Crisp, Greater Wellington Regional Council
Approved for release by:	Fiona Carswell Portfolio Leader – Enhancing Biodiversity Landcare Research

Cite this report as:

Bellingham PJ, Overton JM, Thomson FJ, MacLeod CJ, Holdaway RJ, Wiser SK, Brown M, Gormley AM, Collins D, Latham DM, Bishop C, Rutledge D, Innes J, Warburton B 2016. Standardised terrestrial biodiversity indicators for use by regional councils. Landcare Research Contract Report LC2109 for the Regional Councils' Biodiversity Monitoring Working Group.

Contents

Overview

In 2010, the Technical Group of the Regional Council Biodiversity Forum worked with Landcare Research to develop the Regional Council Terrestrial Biodiversity Monitoring Framework.[1]

This framework is designed as part of 'a national, standardised, biodiversity monitoring programme, focusing on the assessment of biodiversity outcomes, to meet regional council statutory, planning and operational requirements for sustaining terrestrial indigenous biodiversity'

The terrestrial biodiversity monitoring framework adopts the same approach as the ecological integrity framework designed by Landcare Research for the Department of Conservation (DOC) and consists of three components: (i) indigenous dominance, (ii) species occupancy, and (iii) environmental representation.[2] To inform the framework, there are four broad areas: (i) state and condition, (ii) threats and pressures, (iii) effectiveness of policy and management, and (iv) community engagement.

A standardised monitoring framework ensures that data for each measure are consistent among regional councils, which allows for reliable State of Environment reporting. Furthermore, to enable national reporting across public and private land, it is also desirable that where possible, measures can be integrated with those from DOC'sBiodiversity Monitoring and Reporting System (DOC BMRS).[3] The monitoring framework covers most categories of essential biodiversity variables[4] recommended for reporting internationally, addressing species populations, species traits, community composition, and ecosystem structure adequately, but does not address genetic composition and only in part ecosystem function.

This report contains descriptions of 18 terrestrial biodiversity indicators developed within this framework by scientists who worked with regional council counterparts and representatives from individual regional councils. Each indicator is described in terms of its rationale, current efforts to evaluate the indicator, data requirements, a standardised method for implementation as a minimum requirement for each council, and a reporting template. Recommendations are made for data management for each indicator and, for some, research and development needed before the indicator can be implemented.

The terrestrial biodiversity indicators in this report are designed to enable reporting at a whole-region scale. Some of the indicators are also suitable for use at individual sites of

---

[1] Lee and Allen 2011. Recommended monitoring framework for regional councils assessing biodiversity outcomes in terrestrial ecosystems. Lincoln, Landcare Research.

[2] Lee et al. 2005. Biodiversity inventory and monitoring: a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Lincoln, Landcare Research.

[3] Allen et al. 2013. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Lincoln, Landcare Research.

[4] Pereira et al. 2013. Essential biodiversity variables. Science 339, 277–278.

interest within regions. Each indicator is described in terms of a minimum standard for all councils. If implemented by all councils, each measure can then be aggregated to allow national-scale reporting (e.g., for State of Environment reports, or for international obligations such as reporting on achievement of Aichi Targets for the Convention on Biodiversity). Individual councils could add additional measurements to supplement the minimum standards recommended.

Three of the 18 terrestrial biodiversity indicators – Measures 1 ‘Land under indigenous vegetation’, 11 ‘Change in temperature and precipitation’, and 18 ‘Area and type of legal biodiversity protection’ – were implemented and reported on for all regional councils in June 2014. An attempt to implement and report two others at that time – Measures 19 ‘Contribution of initiatives to (i) species translocations and (ii) habitat restoration’ and 20 ‘Community contribution to weed and animal pest control and reductions’ – was unsuccessful because the data needed for these indicators was either not readily available or not collected in a consistent way, and investment will be needed to remedy these issues before they can be reported successfully.

3 Indicator M3: Avian representation

Author: Catriona MacLeod, Landcare Research

3.1 Introduction

This report focuses on M3 ('Avian Representation'), one of three measures used to inform the 'Biodiversity Condition' indicator within the framework. Recommendations for the bird monitoring design are based on review of current New Zealand bird monitoring schemes in relation to best-practice guidelines in the international literature. This work was carried out by Landcare Research for the Regional Council Biodiversity Working Group between July 2011 and December 2013.

To achieve successful conservation outcomes, a combination of biodiversity monitoring, diagnostic research, the testing and proving of management solutions, and their successful incorporation into population- or community-wide management schemes is required (Yoccoz et al. 2001; Wilson et al. 2010; Lindenmayer et al. 2012). The value of biodiversity monitoring has been clearly demonstrated in recent years, for documenting ecosystem change (Both & Visser 2001; DeVictor et al. 2010; Anderson et al. 2011), engaging public awareness in environmental issues, and providing the necessary evidential basis for conservation legislation (Butchart et al. 2010).

Although birds comprise only a small fraction of animal species, they are often selected for monitoring studies (Pereira &Cooper 2006) and to build headline indicators of biodiversity (Schmeller et al. 2012). Four main drivers for this have been identified (Furness & Greenwood 1993; Newton 1998):

- Compared with other taxa, birds are relatively easy to observe and identify, as most species are diurnal and well-known taxonomically.
- Individual nests can be monitored to measure reproductive success, and individual birds can often be fitted with a tracking device or permanently marked (using a tag or leg band), allowing data on their movements, behaviour and life-histories to be obtained relatively easily (Bairlein et al. 2012).
- As many species are high in the food chain, birds are considered good indicators for measuring the status of other taxa and also ecosystem health (i.e. how active the ecosystem is and how well it maintains its organisation and autonomy over time, and its resilience to stress; Constanza et al. 1992).
- Birds represent an iconic component of biodiversity with which policymakers and the general public alike connect.

With many ongoing monitoring programmes in place and many volunteers willing to contribute, birds are often selected as target taxa for global and regional monitoring schemes (Pereira &Cooper 2006). However, as a result, there has been a proliferation of methods and approaches in recent decades (and accompanying debates among the proponents of different approaches). This frequently makes it difficult for conservation managers (or other end-users conducting bird population monitoring) to know how best to proceed for their own specific needs. A review of 144 established bird monitoring schemes in Europe (Schmeller et al. 2012), for example, identified the following design issues as priorities for improvement:

- Ensuring unbiased spatial coverage
- Sampling effort optimisation
- Replicated sampling to account for variation in detection probability
- More efficient statistical use of the data.

3.2 Scoping and analysis

3.2.1 Indicator definition

The Indicator M3 (‘Avian Representation’) aims to quantify the presence of suitable bird species across trophic levels; it is one of three measures used to assess the status of the ‘Biodiversity Condition’ indicator (Lee & Allen 2011).1

We recommend that all species detected are recorded, rather than just one particular subset of species. This approach will allow flexibility and provide baseline data for future measurement of shifts in bird assemblages that were not anticipated at the outset, e.g. the possibility of some currently rare bird species becoming common in the future. For nocturnal species of interest (e.g. kiwi Apteryx spp. and morepork Ninox novaeseelandiae), we recommend that a separate (but complementary) system is developed.

The sampling scheme is appropriate for diurnal bird species at terrestrial sampling locations within a region. This scheme is designed for reporting primarily at the regional or national level. Some habitats currently administered by regional councils (e.g. wetland areas including coastal, braided riverbeds and dune habitats) may need to be monitored independently if species assemblages associated with these habitats are of interest. In particular, we expect that migratory and wetland species associated with these habitats will be poorly monitored by the current scheme.

3.2.2 Indicator statistic

Indicator statistics for Avian Representation could potentially be measured at the population, species or community level. We recommend that regional councils focus on the following three indicator statistics:

- Species richness (the number of species present)
- Occupancy (the proportion of locations occupied by a given species)
- Population density (the number of individuals of a given species within a hectare).

These can be measured either as static (e.g. population size or occupancy) or dynamic variables (e.g. population trend or extinction rate; Box 1).

All indicator statistics should include some measure of the precision of the estimate (e.g. the mean species occupancy or richness with 95% confidence intervals), to allow the reader to determine what confidence can be placed in those estimates and the strength of the inferences that can be drawn from them.

Box 1 Indicator statistics can be measured at population, species or community levels, and as static or dynamic variables

State variables can be the mean or variance estimates.

Population or species level:

1. *Distribution*: Specifying where birds do and do not occur, typically displayed as maps(Bibby et al. 2000) Sampling effort should be uniform (or measured and reported) otherwise the resulting maps will show the distribution of observer efforts as much as the distribution of birds.
2. *Occupancy*: Estimates the proportion of sites occupied by a given species (MacKenzie et al. 2002). Potentially more cost-effective to measure than abundance (Noon et al. 2012).
3. *Abundance*: Can be relative or absolute, with strongest inferences usually drawn from the latter Buckland et al 2008).

Community-level variables can be calculated for all species or subsets of species (e.g. different taxonomic groups or guilds). These are useful for assessing the structure and function of communities and the impacts of management on a variety of species or functional groups of species:

4. *Richness:* Measures the number of species in the community of interest. It is the simplest way to describe community and regional diversity (Gotelli & Colwell 2001).
5. *Evenness:* The equitability of the proportional abundances of the species in the community of interest (Tuomisto 2012). This can provide useful insights into the mechanisms that structure a community and the extent that it is disturbed (Studeny et al. 2011).
6. *Diversity:* Consists of two components, richness and evenness. Most are weighted sums of relative abundances of species, but also could be value-weighted according to ecosystem or economic values or taxonomic distinctiveness to inform management (Yoccoz et al. 2001).

Dynamic variables measure system function (rather than just state), so typically quantify rate parameters (Boulinier et al. 1998). Dynamic variables can be used to explain state and are relevant for both community- and species-level traits:

1. *Colonisation and extinction rates:* Measure vital rates of site occupancy dynamics for a given population or species level (MacKenzie et al. 2003). At the community level, temporal changes in species composition are measured as turnover rates (Magurran et al. 2010).
2. *Trends and rates of change:* Can be absolute or relative, but measuring the percentage change (since an arbitrary baseline year) can provide a more robust way to assess biodiversity trends (Magurran et al. 2010).
3. *Turning points and changing variance:* Turning points identify the timing of significant changes in population or community trajectories (Fewster et al. 2000). Measures of increased variability in biomass and other community attributes can be indicators of change in community composition from one state to the next (Magurran et al. 2010).

Note when measuring trends, it is important to consider these aspects:

- The ecology of the study species (e.g. is it a naturally cycling species?) (Thomas & Martin 1996) and community (e.g. what is the underlying level of temporal turnover in that community?) (Magurran et al. 2010).
- Sampling fluctuations can lead to an alert being triggered when the true reduction (if any) in the population is not of a magnitude to warrant it (Magurran et al. 2010), but smoothing splines can be used to remove short-term fluctuations in population trends (Fewster et al. 2000) and take into account the precision of the change measure within the alerts process (Magurran et al. 2010).
- Small changes in the way that the data are selected for analysis can affect the overall magnitude of trends (e.g. any resulting bias due to adding a constant to count data before log transformation is expected to decrease within increasing abundance).
- The method of trend estimation can affect the magnitude, direction and statistical significance of population trends assigned to species, thus assessing patterns of population change (rather than focusing on the magnitude of calculated trends and variance) may be more important or useful (Thomas & Martin 1996; Buckland et al. 2005).

3.2.3 Reference points for measuring change

Three types of reference points can be used to assess the state of biodiversity across a region and any spatio-temporal trends (Box 2) (Buckland et al. 2008):

- Baseline measures provide the starting points (at some time or state) against which change can be assessed
- Thresholds set some stage at which an alert is raised (e.g. a species has become threatened)
- Targets are set against agreed measurable endpoints and a specified timeline

Biodiversity measures can also be assessed against reference points, either in a static manner (i.e. distance from thresholds or targets) or a dynamic one (i.e. rates of change towards or away from thresholds or targets; Box 2).

Box 2 Setting monitoring goals: approaches, reference points and timelines

1. **Static approaches** include measures of 'population status' (e.g. population size and occupancy) against threshold measures and, at a community level, proportions of species that meet specified management targets, for example:
   - Classify species according to thresholds specified under the IUCN Red List classification system (IUCN 2008).
2. **Dynamic approaches** include the tallying of such numbers or proportions of species within various categories and monitoring changes in the status of these assemblages over time (Magurran et al. 2010). It is important to specify what levels of trend and within what confidence intervals the system aims to detect.
   - The IUCN system, for example, raises an 'amber' alert about a population if it declines by 25% over 25 years and a 'red' alert if it declines by >50% over 25 years (IUCN 2008).
   - The NeoTropical Migratory Bird Conservation Program, for example, defined an effective monitoring system as one that has 90% chance of detecting a 50% decline in a species' abundance over 25 years (Thomas & Martin 1996).
3. Assessments with respect to previously identified thresholds can also **combine both static and dynamic variables**, such as in 'alerts' approaches where sets of quantitative population criteria are used to place species on a 'red', 'amber' or 'green' alert.
   - The UK bird 'alert' listing criteria, for example, assess global conservation status, historical population decline, recent population decline (numbers and geographical range), European conservation status, rarity, localised distribution, and international importance of populations (Eaton et al. 2009).

3.2.4 Reporting frequencies

We anticipate regional councils adopting a sampling design based on a rotating-panel design, with a unique subset of randomly-selected locations (or 'panels') sampled in each year of the 5-year cycle (Table 3-1). If this design is adopted, trends in the biodiversity measures can be estimated, on an annual basis between 'panels' of locations from the second year, and within locations after the first 5-year cycle. It is important, however, that sampling locations in year two and beyond are selected randomly and not according to strata (such as land cover or environmental gradient), or else inference about trend will be confounded by the different strata measured each year.

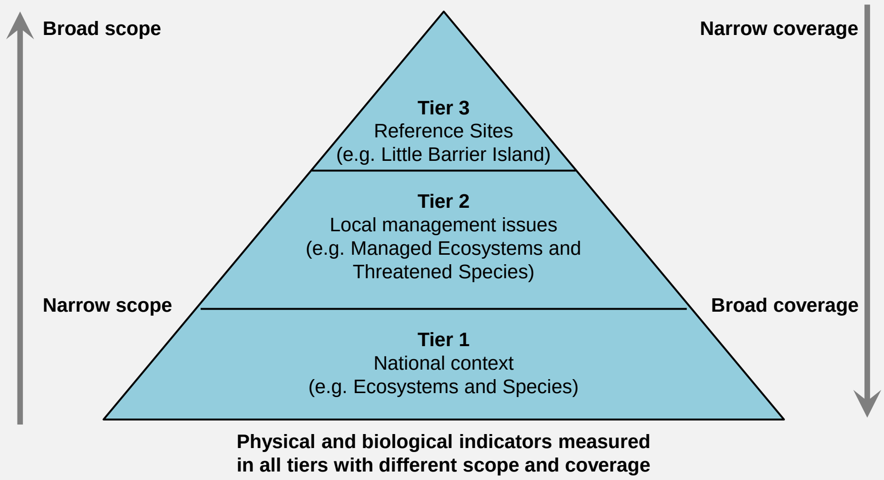
Table 3-1 Schematic specifications (Urquhart et al. 1998) for the proposed rotating-panel design, where a panel consists of a unique subset of randomly-selected sampling locations is sampled each year of the 5-year cycle

Panel	Sampling year																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	■					■					■					■				
2		■					■					■					■			
3			■					■					■					■		
4				■					■					■					■	
5					■					■					■					■

Complementary systems will be required to facilitate monitoring of managed species and places. Such systems would include monitoring of rare and threatened species or communities (Williams et al 2007; Rodriguez et al. 2011; Holdaway et al. 2012), or those with confined distributions, as well as the effects of conservation management efforts at specific locations. Thus, the regional-level sampling proposed here is not intended to address these issues. Addressing specific management-effectiveness questions (e.g. testing the effectiveness of possum control management within the region) may require intensive sampling regimes (e.g. as implemented on DOC Tier 2 monitoring sites).

A trade-off between detail and scope or coverage is a practical limitation faced by all monitoring programmes. DOC uses a nested hierarchy (Box 3) to collect information with different levels of scope and coverage.

Box 3 Hierarchical nested monitoring adopted by the DOC Biodiversity Monitoring and Reporting System.



- **Tier 1.** The lowest level represented is monitoring that has broad spatial and temporal applicability (e.g. *National Ecosystems and Species*). This level provides geographic and interpretive context for data collected for *Managed Ecosystems* or *Managed Threatened Species* (Tier 2 and Tier 3).
- **Tier 2.** The middle tier indicates enhanced investigation effort that is limited in spatial and temporal extent but focused on management-driven impacts and outputs (*Managed Ecosystems* or *Managed Threatened Species*).
- **Tier 3.** Monitoring conducted intensively at a few sites (e.g. Waitutu, Eglinton, Craigieburn). These sites are useful for understanding interactions and allowing the development of predictive models. These intensive monitoring areas may become reference sites or benchmarks against which other sites may be compared. Intensive investigations aid in interpreting Tier 1 and Tier 2 data.

3.2.5 Reporting hierarchies

Information can be presented for all species, different subsets of species or individual species. Bird species can be grouped according to their origin (native or introduced) or functional traits or trophic levels (e.g. insectivores vs seed-eating species).

3.2.6 Spatial and temporal analysis

In the short term, it will be feasible to report on *Avian Representation* status at regional and national levels. Where sampling effort is sufficient, it will also be feasible to report on *Avian Representation* status within the predominant environments and land-use types at regional and national scales. After the first set of remeasurements, the system will report on the status of biodiversity measures relative to baseline measures from the initial survey at regional and national scales, as well as within predominant environments and land-use types. In the longer term, the system will report on trends in the biodiversity measures and evaluate these trends against agreed standards or limits.

3.2.7 Relationships between indicators and present patterns

We recommend integrating sampling protocols for the *Avian Representation* measure with those of the closely aligned M16 (*Changes in abundance of animals susceptible to introduced* *herbivores and carnivores*). Other measures could be used to interpret any spatial and temporal changes in the avian representation metrics. Measures of *Habitat Loss* and *Land under Indigenous Vegetation* could be used, for example, to test for evidence of land-use-change impacts (e.g. agricultural intensification and loss of indigenous vegetation) on bird populations. Similarly, the Biodiversity Protection measures could be used to assess whether areas subject to protection policies provide enhanced biodiversity outcomes relative to areas without protection. Such analyses could thus inform management and policy at regional and national scales.

3.2.8 Assessment of existing methodologies

Bird monitoring can take either surveillance or question-driven approaches, being motivated either by curiosity or by scientific questions and/or management issues (Yoccoz et al 2001; Field et al 2007; Lindenmayer & Likens 2010; Jones et al 2011; Jones et al 2013). Monitoring can be aimed either at the birds themselves or at bigger picture environmental goals (i.e. using birds as indicators) (Furness & Greenwood 1993; Newton 1998; Pereira & Cooper 2006). Different users tend to ask different questions of monitoring depending on their needs or interests (Figure 3-1), influencing the approaches (what is measured) and methods (how it is measured) chosen.

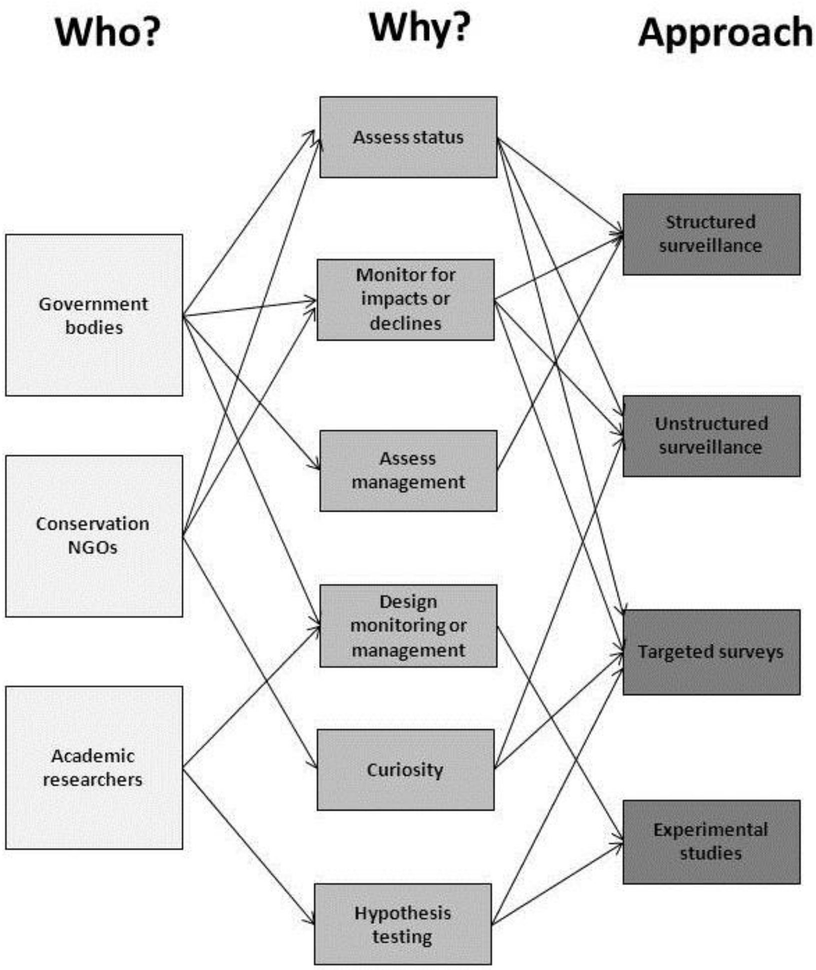


Figure 3-1 Purposes for monitoring and the approaches used.

The *Avian Representation* measure requires standardised field sampling and classification of birds into relevant guilds. A number of bird monitoring schemes are currently applied in New Zealand (Table 3-2), each using different monitoring designs and field sampling methods. There is currently no standard classification of feeding guilds for birds in New Zealand, with independent studies using their own interpretation of the literature to classify species (Hoare et al. 2012; MacLeod et al. 2012).

Footnotes to Table 3-2 (over page)

[1] Department of Conservation Biodiversity Monitoring and Reporting System; Lee et al. 2005; Allen et al. 2009b; MacLeod et al. 2012e; Macleod et al 2012a

[2] Agricultural Research Group on Sustainability; MacLeod et al. 2012c

[3] Spurr 2012

[4] Bull et al. 1985; Robertson et al. 2007

[5] Scofield et al. 2005

[6] Sullivan 2012

Table 3-2 Summary of bird monitoring initiatives in New Zealand (GOV = government, ACA = academic, IND = industry, NGO = non-government)

Approach	DOC BMRS[1]	ARGOS[2]	Garden Bird Survey[3]	NZ bird atlases[4]	eBird[5]	NatureWatch[6]
Governance	GOV	ACA, IND	NGO, ACA	NGO	NGO	NGO, ACA
Objective	Assess status Monitor for impacts Assess management Early-warning system	Assess status Monitor for impacts Assess management	Assess trend Raise awareness	Assess status	Curiosity Assess status	Curiosity
Structured surveillance?	Yes	Yes	Semi	Semi	No	No
Species variables	Species richness Species occupancy Species abundance	Species richness Species occupancy Species abundance	Species occupancy Species abundance	Inventories of species of interest Species distribution	Inventories of species of interest	Inventories of species of interest
Statistics quantified	State (and trend)	State (and trend)	Trend (and state)	State (and trend)	Usually state, occasionally trend	Usually state, occasionally trend
Reference points	Baselines from initial survey	Baselines from initial survey	Baselines from initial survey	Baselines from initial survey	Not specified	Not specified
Spatial scope	Public conservation lands at a national scale	Farmland within three sectors	Urban at national scale	National scale	Locations of interest to personnel	Locations of interest to personnel
Temporal scope	Rotating-panel design over a 5-year cycle	c. 2–3 year intervals	Annual	c. 20-year intervals	Variable	Variable
Repeated measures	Yes	Yes	Some	Possibly	Not specified	Not specified
Bird count technique	Modified 5-min Bird Count, incorporating distance sampling	Distance sampling transects & point counts	Timed counts, maximum number observed	Roving records of species lists	Ad hoc observations	Ad hoc observations
Repeated counts	Yes	Yes	No	Some	Possibly	Possibly
Detection probabilities	Yes	Yes	No	No	No	No
Record sampling effort	Yes	Yes	Yes	Yes	Typically no	Typically no
Field personnel	Professional	Professional/student	Citizen science	Citizen science	Citizen science	Citizen science
Database development	Ongoing	Established	Ongoing	Established	Established	Established
Analysis controls for sampling effort variation	Yes	Yes	No	No	Typically no	Typically no (but see Sullivan 2012)
Precision	Yes	Yes	Yes	No	No	No
Reporting	Annual	c. 2–3 years	Annual	20-year intervals	No	No

3.3 Current approaches employed by regional councils

- *Regional-scale monitoring efforts:* Currently limited to two regions: Auckland (but focusing on a subset of the landscape – remnants of woody vegetation); and Greater Wellington (a pilot study testing feasibility of using 8 × 8 km grid to sample pastoral landscapes, recognising that information on other dominant habitats is available from DOC).
- *Site-focused surveys:* Most current bird monitoring efforts are focused on measuring the impact of management such as pest control or restoration activities (e.g. Greater Wellington Regional Council; Hawke's Bay Regional Council; Environment Waikato[v]) (Fitzgerald & Innes 2013). There is potential to establish coordinated monitoring among these monitoring locations akin to a Tier 2 monitoring system (Box 3). The key challenge here is variation in management approaches and different scales of monitoring vs management.
- *Bird count methods employed:* The five-minute bird count is the primary method used, with fieldwork carried out by private contractors (e.g. Hawke's Bay) or in combination with in-house skills (e.g. Greater Wellington; Environment Canterbury) or community groups (e.g. Environment Canterbury).
- *Analytical capability available:* This varies among regional councils, with some better resourced than others. This is a specialist skill-set perhaps best provided by a third party; this is also better from an audit perspective (akin to the DOC/KPMG audit/auditor general review process).
- *Regular reporting:* There is currently only limited reporting – the primary focus being state of the environment reporting (e.g. Auckland Council). Reporting for other purposes could include community engagement projects (e.g. Hawke's Bay).

3.3.1 Monitoring objectives and sampling designs

Bird monitoring schemes currently underway in New Zealand are governed by a range of different parties (Table 3-2), including government agencies (DOC's Biodiversity Monitoring and Reporting System, DOC BMRS), academic research institutes (e.g. the Agricultural Research Group on Sustainability, ARGOS, which works closely with industry) and non-government organisations (primarily the Ornithological Society of New Zealand) or partnerships between multiple parties (e.g. the New Zealand Garden Bird Survey). Although the monitoring goals are not always explicitly stated, most schemes appear to aim to assess the status of bird populations and communities, with few being specifically designed to assess and monitor management impacts. The schemes range from highly structured surveillance designs (DOC BMRS and ARGOS) to semi-structured ones (Garden Bird Survey) to those using unstructured surveillance approaches (e.g. eBird, NatureWatch NZ).

---

[v] Hamilton Halo project: http://www.waikatoregion.govt.nz/Environment/Natural-resources/Biodiversity/Hamilton-Halo/

For the regional council Terrestrial Biodiversity Monitoring Framework the key will be to select a scale, design and intensity of monitoring that are appropriate for its purpose, as this will influence the extent and strength of inferences that can be drawn from the monitoring data (Yoccoz et al. 2001). Strongest inferences are typically made when the measured variables have low bias (minor systematic under- or over-estimation) and high precision (a low level of uncertainty) (Thompson 2002; Buckland et al. 2008; Snäll et al. 2011). Having established an initial design (MacKenzie & Royle 2005; Voříšek et al. 2008), the sampling strategy should be re-evaluated given the available resources (Appendix 3-1), to ensure that it will be feasible to implement in the field and will provide adequate representation and precision to address study objectives (Gregory 2000; Field et al. 2005). If not, the objectives and design either need to be revised or the required resources secured (Magurran et al. 2010).

3.3.2 Species metrics and monitoring reference points

Different monitoring approaches will provide different species metrics (Figure 3-2). In general, atlases provide useful preliminary information about bird distributions or species inventories within a region, but to detect trends and direct management and policy, more detailed and regular surveys will be required (Bibby 1999). While smaller-scale (but more intensive) monitoring may be better suited for accurate and precise abundance measures for single species, less intensive monitoring at larger spatial scales may be better suited for community measures such as species richness, and monitoring to gain information on population trends generally needs long time-series of data to separate trend from random variance.

Most New Zealand schemes currently focus on measuring status and change relative to baselines derived from the initial surveys. Some aim to measure trend but currently do not have sufficient information to do so (except possibly the Garden Bird Survey).

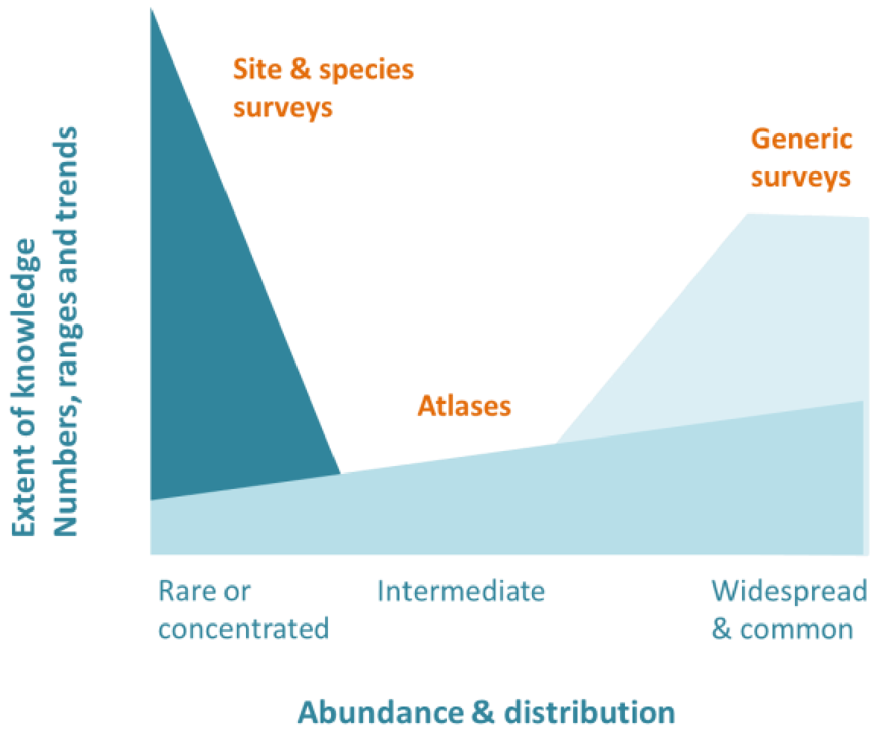


Figure 3-2 Survey design and the development of knowledge on trends and numbers of birds. Different survey approaches work differently according to the pattern of numbers and distribution of the species. Adapted from Bibby (1999).

3.3.3 Spatial and temporal scope

The spatial and temporal scope of the different bird monitoring initiatives in New Zealand vary extensively (Figure 3-3), with only the bird atlases aiming to provide information at a national scale. Some focus on particular land uses (conservation, agricultural or urban landscapes), while others concentrate on specific locations of interest to the observer. The frequency and timing of sampling events also vary widely among the schemes. These differences in spatial and temporal scope make it difficult to directly compare and collate information collected from these different schemes (MacLeod et al. 2013).[vi] In addition to considering the spatial scope of monitoring underway under other schemes, assessing the power of those schemes to realistically detect changes in bird community composition is also important (Figure 3-3).

[vi] Assessing the feasibility of drawing from multiple data sources for reporting on biodiversity status and trend information is the focus of a new MBIE-funded project, 'Trustworthy biodiversity measures – using birds as a proof-of-concept' (MacLeod et al. 2013).

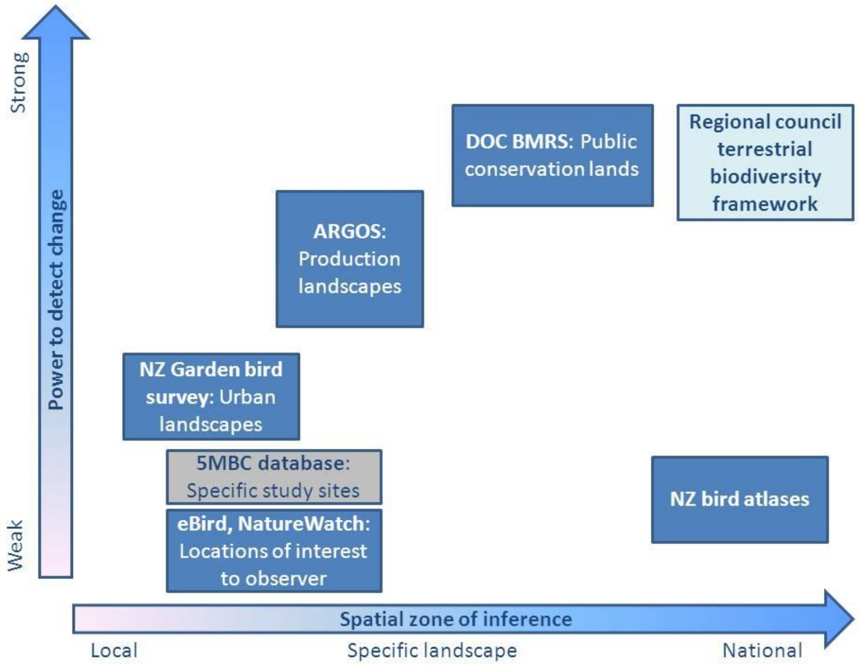


Figure 3-3 Comparing bird monitoring schemes currently implemented in New Zealand to highlight differences in their spatial zones of inference and potential power to detect change in avian community composition.

Schemes using *structured surveillance* approaches implement standardised sampling protocols at specified sampling locations and those locations are repeatedly sampled at regular intervals at a similar time of year (e.g. DOC BMRS and ARGOS). Using repeated measures from the same sampling locations over time can increase the power of a given monitoring design to detect changes in trends, relative to a design that measures a new set of locations at each sampling event (Monks & MacLeod 2013).

- *DOC BMRS:* Benefits of alignment with this scheme would include providing a representative sample across the region, with DOC covering the costs of monitoring for c. 32% locations at the national scale, although some regions will benefit more from this partnership than others (Appendix 3-2)
- *NZ Sustainability Dashboard:* This sustainability assessment and reporting tool (Manhire et al. 2012) is currently being developed[vii] for multiple primary industry sectors within New Zealand. It combines internationally-recognised frameworks and their key generic sustainability performance indicators (KPIs), with complementary KPIs developed specifically for New Zealand and the participating sectors (Hunt et al. 2013). The environmental monitoring framework design is closely aligned to the DOC and regional council biodiversity monitoring and reporting systems (MacLeod & Moller 2013). This provides an opportunity for regional councils to contribute and obtain data to assess sustainability of land management practices at regional, national and industry levels.

[vii] This initiative is being led by the Agricultural Research Group On Sustainability (ARGOS). http://www.nzdashboard.org.nz/

Semi-structured surveillance designs (e.g. the atlas of bird distribution and the New Zealand Garden Bird Survey) are likely to have reduced power to detect change (Bibby 1999; Bibby et al. 2000). This is primarily due to temporal changes in the spatial scope of sampling effort, which makes it difficult to distinguish whether any observed changes are due to real changes in bird populations or if they simply reflect changes in the areas being sampled. Also, sampling may be biased towards locations of interest.

- *New Zealand Garden Bird survey:* Extending the 8 × 8 km grid at national scale would provide a relatively small number of locations within urban landscapes (Appendix 3-2). As a good example of an indicator for reporting on community engagement, it could be a potential mechanism for overcoming difficulties in gaining access to private land for monitoring. The following potential sources of bias have not yet been formally investigated but are important considerations: (1) large variation in bird identification capabilities (e.g. Adélie penguins, an Antarctic species, being observed!); (2) the method does not currently account for variation in species detectability among and within regions; and (3) survey effort may be biased towards particular locations, for example gardens close to parks or reserves where birds are more abundant or diverse.
- *Future New Zealand bird atlases:* As the sampling protocols employed in previous iterations of the New Zealand bird atlases were flexible, observers may have targeted locations where they were more likely to encounter a wide range of species or those of conservation concern. Hence, there is opportunity to strengthen inferences that can be drawn from these data using a more structured surveillance approach.

Unstructured surveillance approaches will typically have very low power to detect change. This is because both the spatial and temporal scopes of sampling are highly dynamic and rarely specified and maintained. Alternatively, the spatial and temporal scopes can be clearly defined but will be focused on locations of interest to the observer (Sullivan 2012), hence limited inferences can be drawn from such information for regional and national reporting purposes.

- *eBird* and *NatureWatch*: There is potential to harness this citizen effort to facilitate a structured surveillance approach. Currently data are too patchy (temporally and spatially) to provide meaningful information at national and regional scales (e.g. see relevant international reviews: Snäll et al. 2011; Dickinson et al. 2010; Conrad & Hilchey 2011).
- *Five-minute bird count database:* The five-minute bird count method (5MBC) (Dawson & Bull 1975) has been the predominant bird monitoring technique used in New Zealand over the last 40 years (Hartley 2012). At least 120 000 counts are currently held in a central database (administered by DOC) but these data were primarily collected in short-term studies that were patchily distributed across the country (Figure 3-4).

Figure 3-4 Distribution of five-minute bird count studies currently held in the Department of Conservation's 5MBC database. Source: Hartley (2012).

3.3.4 Bird count techniques

Counting birds can be difficult because counts not only vary over space and time due to actual differences in species composition and abundance, but also due to differences in detection probabilities of species and individuals among counts (Box 4) and differences associated with measurement and misclassification errors (Simons et al. 2009). Given that absolute counts are rarely feasible, most studies aim to sample the community or population of interest. A large number of methods exist for counting birds. Most of the 'bird-count-method' debate is centred on the importance of detection probabilities, with counts being classified into two groups according to whether they explicitly measure and account for variation in detectability or not ('adjusted' or 'unadjusted' counts; Appendices 3–5).

The bird count methods used in New Zealand schemes (Table 3-1) encompass both adjusted (e.g. DOC BMRS and ARGOS) and unadjusted counts (e.g. Garden Bird Survey, bird atlases, eBird and NatureWatch). Adjusted counts, which account for variation in species detection probabilities (Box 4), include repeated counts (to measure species richness and occupancy; Box 5) and distance sampling methods (used to estimate population density; Appendices 4–5).

3.4 Data storage and reporting

Most regional councils (and other organisations) store their data in an ad hoc manner (e.g. using electronic spreadsheets on individual computers or local servers). However, recently some organisations have developed independent databases (e.g. OSNZ's bird atlases, DOC's 5MBC database) and online data repositories (e.g. eBird, NatureWatch, Garden Bird Survey, Global Biodiversity Information Facility) to improve data management.

Some regional councils hold a large amount of five-minute bird count data. However, this information is currently not readily locatable or available as there is no data storage system that all regional councils (or other stakeholder groups) can use to store bird data. This presents a number of data management and utilisation issues. For example, if standardised protocols for recording and storing the metadata and bird count information[viii] are not implemented, this presents difficulties for locating, mobilising and interpreting existing bird data. Overcoming these issues is particularly important for DOC and regional councils if their respective monitoring frameworks are to be compatible and able to inform on state of the environment reporting. Better data-recording and management protocols are required if multiple sources[ix] are to contribute information on a common basis for reporting regionally and/or nationally.

[viii] http://www.doc.govt.nz/conservation/native-animals/birds/five-minute-bird-counts/resources/

[ix] The BioData Services Stack project recently funded by TFBIS could provide some tools for mobilising existing bird count data held by regional councils.

Box 4 Detection probability

Definition and components

Detecting birds is often complicated because some birds move, while others are inconspicuous or actively move to avoid the counter (Elphick 2008). There are two components to detection probabilities (Alldredge et al. 2008):

- A probability that a bird is available for detection
- A probability of detection, conditional on its availability.

Bird detectability may vary in relation to three types of factors (individually or in combination (Alldredge et al. 2008; Buckland et al. 2008; Elphick 2008; Rozenstock et al. 2002):

1. Observer ability to detect and accurately identify birds
2. Environmental variables that affect bird behaviour and observer efficiency
3. Physical and behavioural traits of birds that make them more or less conspicuous to human observers.

Incorporation into abundance estimates

Bird count techniques all involve the collection of a count statistic (*C*), typically the number of birds seen or heard at a given point or along a transect (Nichols et al. 2002).This count statistic is denoted by the formula: $E(C_i) = p_i N_i$, where N_i is the true abundance and p_i is the detection probability, associated with a given location and time period that the count was undertaken (*i*).

- *Unadjusted counts* do not measure detection probability, but instead assume that detection probabilities will be similar for the times and places for each abundance comparison to be made (i.e. $p_i = p$ for all *i* in the comparison). Thus, unadjusted counts report an index (C_i) that measures the proportion of the population that is counted.
- *Adjusted counts* collect data in a manner that allows estimation of the detection probability at the given location and time period (*i*) and so permits estimation (^) of the population size: $\widehat{N_i} = \frac{C_i}{\widehat{p_i}}$. The resulting population estimate can then be used to draw inferences about changes in abundance over time and/or space.

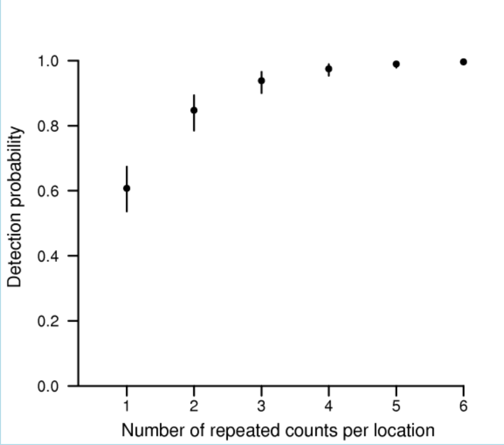
Box 5 Measuring occupancy for an iconic bird in urban parks

'Citizen science' initiatives monitoring the success of restoration activities require simple and robust tools if meaningful data are to be collected. Using an urban monitoring study of the bellbird (*Anthornis melanura*), we were able to offer advice and guidance on best practice for such monitoring schemes (MacLeod et al. 2012f).

Three independent surveys were undertaken across 140 locations in Christchurch's urban parks. Six repeat five-minute point counts were undertaken at each location per survey.

A single five-minute count had c. 60% chance of detecting bellbirds at a location where they were present, while the cumulative detection probability increased to almost one after five repeat counts per survey.

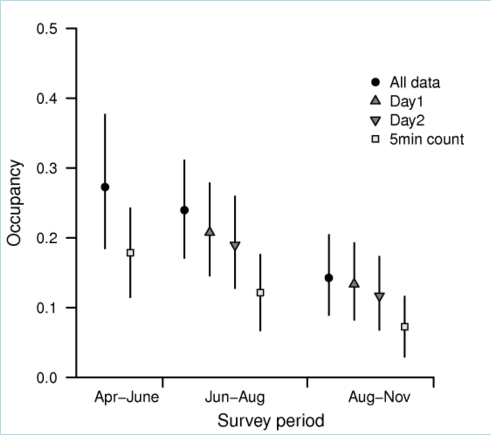
Detection probabilities were used to calculate unbiased occupancy estimates.



Occupancy estimates calculated using three replicate counts ('Day1' and 'Day2') were lower, but not statistically different, than those based on six replicates ('All data').

Robust estimates of bellbird occupancy require at least three repeat counts per location per survey within a short time frame (to minimise the risk of recording false absences).

Ideally, multiple locations should be surveyed concurrently. Prolonging the time taken to complete a survey of all locations increases the risk of bird movement occurring, and thus represents a shift from measuring occupancy to measuring the relative 'use' of different locations.



3.5 Development of a sampling scheme

3.5.1 Field sampling framework

A rotating-panel design, compatible with the New Zealand Land-Use and Carbon Analysis System (LUCAS) (MfE 2005) and the DOC BMRS (Allen et al. 2009b), is recommended for the field surveys (Appendix 3-2). Using a national infrastructure (an 8 × 8 km grid; n = 4084 sampling locations) established to measure carbon, vegetation structure and composition would provide regional councils with a regular, unbiased framework for sampling. Repeated measurements of each sampling location would occur at 5-yearly intervals, with a unique subset of randomly-selected locations surveyed in each year of the 5-year cycle.

The information collected using this framework would be suitable for integrating and reporting at both regional and national scales, with DOC surveying c. 32% of sampling locations at the national scale (but on public conservation land only) and between 8% and 86% at a regional scale (i.e. within each region, Appendix 3-2). At both national and regional scales, strongest inferences on the status and trend of biodiversity will likely be drawn for the two predominant landcover classes: forest (32%) and grassland/sedgeland/marshland (52%; Appendix 3-2).

3.5.2 Bird count methods

The optimal time for the bird surveys is mid-September to mid-October, which is early in the breeding season for most bird species and when male birds sing most consistently. Field sampling should proceed, in each year, from north to south and east to west to 'follow the spring season'. Each sampling location should be permanently marked, wherever feasible, to allow for repeated sampling at that location. Assuming that the DOC BMRS protocol is adopted, vegetation measurements are all made within a fixed 20 × 20 m plot. Data on mammal pests and common birds are collected within a much larger area (220 × 220 m), using a design that radiates out from the edges of the central vegetation plot (Figure 3-5). Standardised field sampling protocols are used for both the vegetation and animal surveys (Allen et al. 2009b; MacLeod et al. 2012e; DOC 2012).

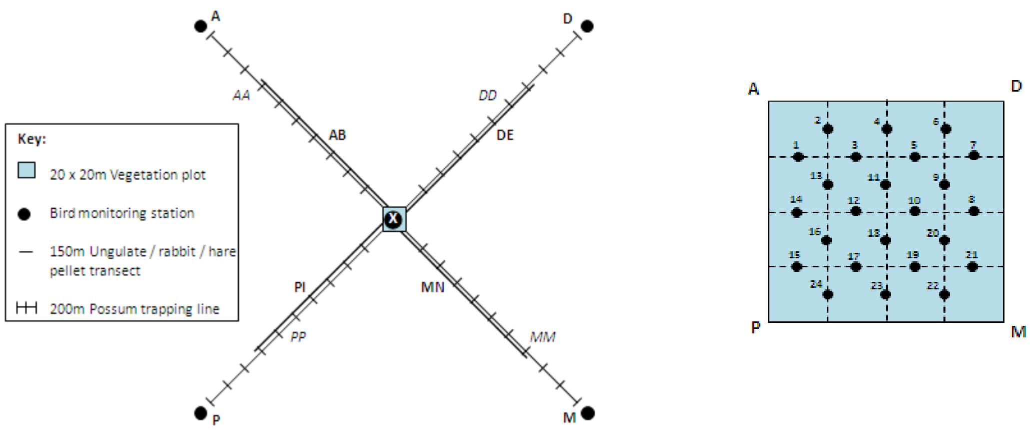


Figure 3-5 Layout of the animal-survey sampling units in relation to the vegetation plot at each sampling location.

A cluster of five count stations (200 m apart) is set up at each location (Figure 3-5), with bounded bird-point counts carried out on two consecutive days at each station (DOC 2012; MacLeod et al. 2012e). One count station is centred on the vegetation plot and one located 200 m directly away from each plot corner (Figure 3-5). Each location is considered an independent sampling unit, at which species richness, occupancy, and density are estimated (using data from the bounded bird-point counts collected from the cluster of five stations, i.e. 10 counts from five stations sampled twice).

Surveys are not undertaken in heavy rain, strong winds or poor visibility. To minimise the effects of diurnal variation in vocalisation and to ensure comparability with historical 5MBC data, all counts are initiated at least one hour after the official sunrise time for the sampling location (hence surveying only diurnal species; sunrise times for each day and location can be calculated using the ‘sunriset’ function in the ‘maptools’ package in R) (Lewin-Koh et al. 2008). Field teams should initiate counts one hour after sunrise and complete counts as quickly as possible, but the timing of bird surveys may be constrained if the same team also has to set up and check possum trap-lines (Allen et al. 2009b).

For each replicate bird survey, a ten-minute bird count (10MBC) is used. Distance-sampling procedures are incorporated into the first five minutes (5MDist) of each 10MBC, using a point-transect sampling approach (Buckland et al. 2001). During the 5MDist, the number of individuals detected (flock size) at each observation is recorded, in addition to whether individuals were initially heard or seen, and the horizontal radial distance from the count station to the point of first detection. The observer is asked to identify in which distance-band the bird was located (0–8 m; 9–16 m; 17–25 m; 26–45 m; 46–100 m; and >100 m from the count station). Birds only observed flying overhead (i.e. not associated with the sampling location) are not recorded, except for skylark, for which the horizontal radial distance to the bird is recorded. Where birds in close proximity to the count station are obviously disturbed by the approach of the observer, care is taken to note the identity and, where possible, original location of those birds. The observer also records whether or not birds moved towards them. During the 6–10 min period of the 10MBC, a modified 5MBC is to be conducted. This is a simple tally of all bird species seen or heard (including overhead observations) and recorded as either ‘Near’ (0–25 m), ‘Far’ (25–100 m) or ‘>Far’ (>100 m) within a 5-min period over an unbounded (>100 m) distance. A rangefinder may be useful for these observations.

Habitat measures are collected within a 20 × 20 m plot at each bird count station, by carrying out a reduced Recce within the plot. We recommend following the standard Recce protocols (Hurst & Allen 2007) to characterise the topography and vegetation at each station (i.e. altitude, aspect, slope, physiography, drainage, cultural, surface and ground cover characteristics and overall vegetation tier cover classes). Overall vegetation-tier cover classes should only be provided for Tiers 1–6 as per the protocol for woody vegetation (and not subdivided Tiers 5 and 6); presence of species in Tier 7 (epiphytes) is noted. (Note: the DOC protocol (DOC 2012) recommends more detailed measures, which will require more time and specialist knowledge.)

DOC is currently investigating the feasibility of replacing observers in the field with automated recording devices for measuring bird community composition. However, these are new methodological developments, which are still in their infancy, and require comprehensive ground-truthing before they can be relied upon to cost-effectively deliver useful information (Elphick 2008). Thus we caution against adopting automated sampling protocols at this stage.

3.5.3 Trade-offs and modifications in sampling design

The rotating-panel design recommended for regional councils is a compromise between two extremes: (1) sampling the same locations each year or (2) sampling new locations each year. Repeated sampling at the same locations results in more precise estimates because of smaller variability, but the estimates will be relatively biased as a result of poor coverage across the landscape. Alternatively, sampling at different locations each year gives better coverage of locations, resulting in less biased estimates, but at the cost of increased variability due to lack of repeated sampling.

Any modifications to the sampling intensity (i.e. the number of sampling locations surveyed) should employ a grid size compatible with the 8 × 8 km grid (i.e. either a reduced or expanded subset nested within that framework). If the sampling intensity was reduced, for example, we recommend sampling a subset of the existing framework, using sampling locations occurring within the 16 × 16 km grid (n = 1019 sampling locations nationally). Alternatively, if the aim was to increase the sampling intensity, we recommend establishing the sampling grid at a finer scale that nests within the original framework, with a 4 × 4 km and 2 × 2 km grid increasing the number of sampling locations 4-fold and 16-fold, respectively.

Using existing bird data collected for forest and farmland habitats nationally, we consider the potential power of a regional scheme to detect changes in species occupancy and densities in relation to the species traits and the sampling intensity (i.e. number of locations sampled; Box 6; Appendix 3-6). We strongly recommend consistency in the bird count methods used among regions, as altering the field protocols can have significant consequences for integrating and interpreting the data (e.g. Box 7).

Box 6 Power to detect change in avian metrics

Detection probabilities vary among species, habitats and seasons (MacLeod et al. 2012 d)*, for example:*

- Only a third of species detected in farmland (*n* = 51) had detection probability ≥0.2, compared with two-thirds of species in forests (*n* = 32).
- Some native species (e.g. grey warbler, fantail tomtit, silvereye) are twice as difficult to detect in farmland as they are in forest habitats.

Metrics used to assess status and trend will depend on the information available:

- Recent national surveys of forest (MacLeod et al 2012a) and farmland (MacLeod et al. 2012c) indicate that it will be possible to calculate densities for less than half of the species detected.
- For widespread and common species, in particular introduced species, measuring changes in density may be more informative than changes in occupancy.

Standardised power calculations were used to test the ability of a regional scheme (MacLeod et al 2012d) *to detect (Appendix 3-6 – Informing trade-offs in sampling design):*

1. ***Absolute* changes in species occupancy between two time periods. The scheme could detect**:
   - moderate (0.25–0.45) to large (0.46–0.65) changes for c. 30% of native bird species at a regional scale, assuming c. 120 sampling locations were surveyed in each time period
   - large (0.46–0.65) changes in occupancy within forests, but not in non-forest areas, assuming c. 40 sampling locations were surveyed within each landcover class in each period
   - moderate (0.25–0.45) changes in occupancy within forests, but only very large (≥ 0.65) changes in non-forest areas, assuming c. 80 sampling locations were surveyed within each landcover class in each period.

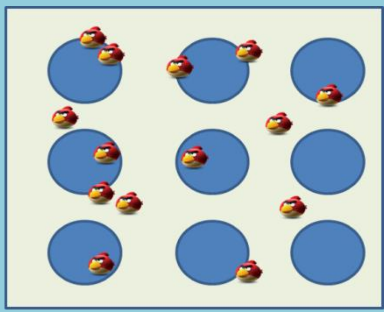
2. ***Relative* changes in species occupancy between two time periods. The scheme could detect**:
   - moderate (25%) changes at the regional scale for most species with moderate to high detection probabilities (p ≥ 0.4) if c. 160 sampling locations were surveyed
   - moderate (25%) changes in forest and non-forest habitats for most species with moderate to high detection probabilities (p ≥ 0.4) if c. 80 sampling locations were surveyed within each landcover class.

3. ***Relative* changes in population density of a species between two time periods. The scheme could detect**:
   - small (c. 5%) to moderate (c. 10%) changes in density for native species in closed forests and common introduced species in open farmland habitats (when coefficient of variance estimates for densities are ≤20%, and ≥40 sampling locations are surveyed in each landcover class)
   - moderate (c. 10%) to large (c. 20%) changes in density for native species in closed forests and common introduced species in open farmland habitats when density estimates are less precise (i.e. coefficient of variance estimates for densities are 21–40%, and ≥40 sampling locations are surveyed in each landcover class).

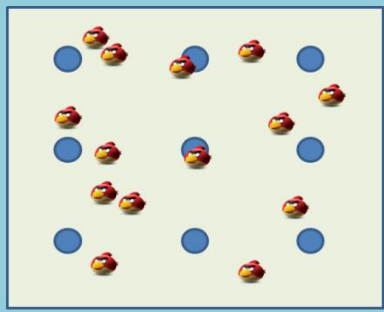
   In both cases, the power to detect changes in densities would be substantially reduced if either a different subset of sampling locations were measured at time 1 and time 2, or if two sampling locations from different landcover classes were being compared.

Box 7 Effects of changing the scale of the sampling units used

- Occupancy decreases as your sampling unit gets smaller
- This presents an issue for combining different sources of data.



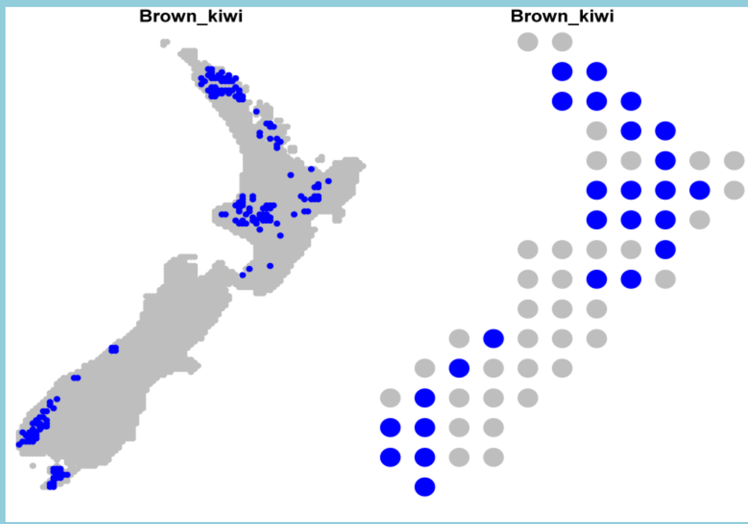
Present in 7 of 9 plots (78%)



Present in 2 of 9 plots (22%)

Brown kiwi data example from the NZ bird atlas (1999–2004) (Robertson et al. 2007)using different-sized grids:

- **10 × 10 km grid** (species detected in 176 of 3166 squares), where occupancy = **0.06** (left map)
- **100 × 100 km^2 grid** (species detected in 26 of 61 squares), where occupancy = **0.43** (right map)



3.5.4 Field delivery programmes

For the monitoring system to be successfully implemented (in the short and long term), field training and scheduling issues need careful consideration.

- *Feasibility of the methods:* Field experience in sampling vegetation in 20 × 20 m LUCAS (MfE 2005) forest and shrubland plots showed that of 1372 sampling locations nationally, 118 (8.6%) were not sampled (giving 1254 established) either because access to a location was denied or because the location was too steep to be sampled safely (Allen et al. 2009a). Steep terrain is likely to be a bigger constraint to obtaining data at sampling locations for birds, as the bird surveys sample from a larger scale (4.84 ha) than the vegetation measures (0.04 ha) (Allen et al. 2009a; MacLeod et al. 2012e). To maintain safety and also ensure that sampling can take place in some locations, the bird count stations at the end of the possum trap-lines (Figure 3-5) can be moved between 25º and 65º along the 45º bearing from a vegetation plot edge. If a slope threshold is used to exclude sampling locations, then the sampling universe needs to be specified accordingly (e.g. as those lands with slopes ≤35º). Dense vegetation can also be a constraint to obtaining accurate distance data at count stations for use in distance-based measures of abundance (Simons et al. 2009). This problem will be overcome, to some degree, by using estimates of distance in fixed classes, for both visual and auditory data. Bird survey teams will need to have excellent bird identification skills (sight and especially calls; MacLeod et al. 2012e) and distance measurement skills (Simons et al. 2009). The presence of other fieldworkers in the vicinity of a count station is expected to increase sampling error, especially in open habitats, where birds are disturbed by fieldwork activity. Such disturbance should be kept to a minimum, with the bird observer ideally completing the bird counts before other measures (e.g. for vegetation and vertebrate pests) are undertaken.

- *Training:* A field-team coordinator, with strong project management skills, will be required to run the field programme. Specialist field teams, with relevant methodological skills, must be briefed on the logistical and operating protocols, as well as the field survey protocols. In addition to field safety training, field teams will need to gain technical experience handling the relevant equipment, recording relevant time-budget and operational data (to inform logistic planning and budgeting in the future), and guidelines on how to prioritise their field effort when time-constraints occur (e.g. owing to poor weather). Note there is a risk that sampling-bias issues may arise within and between regions if field teams train and work in isolation from each other. It is important, therefore, that these teams train together and touch base regularly at regional and national scales to ensure protocols are consistent and coordinated.
- *Scheduling:* Before implementing the field programme, a scoping exercise is necessary to determine the availability of the field skills and personnel required to implement the survey methods at the regional scale; training schemes will be needed to address shortages (e.g. DOC's pilot study identified shortages in bird skills; Allen et al. 2009a). Six months before the field season, a work plan should be developed to ensure cost-effective coordination of field teams; this should include an assessment of access issues, the feasibility of implementing surveys at each location, and field gear requirements, as well as operational and field safety planning. One month prior to the field season, relevant training workshops should be run, with field teams then assisting with the final stages of field preparations. During the field season, the field coordinator must oversee the daily logistic requirements of the team, regularly review their schedules, and ensure that data management protocols are being maintained. Data checking, management and reporting processes should be completed as soon as possible after completing the field season. Audit protocols should be implemented, so that 10% of plots are audited throughout the field season. We recommend that regional councils coordinate with DOC and potentially with other regions to share skills and skilled staff and contractors if possible.

3.5.5 Cost estimates

Field cost estimates for the DOC BMRS pilot study (Allen et al. 2009a; MacLeod et al. 2012e) were high per sampling location (Table 3-3). For regional councils, we anticipate that travel times and costs should be substantially reduced:

- In regions that have a large number of readily accessible sampling locations (e.g. low elevation, open or modified landscapes).
- DOC is likely to cover costs of monitoring for c. 32% locations at the national scale, with some regions benefiting more from this partnership than others (Appendix 3-2).

The differing costs of volunteers and professionals, and whether it is worth spending money, time and resources on training volunteers, needs to be weighed up (Dickinson et al. 2010). Volunteers generally deliver poorer quality data, potentially requiring a greater investment at the analytical stage, and even then likely having less inferential power compared with professionally collected data. However, the cost of utilising professionals typically prohibits the execution of larger-scale designs. It has been recommended elsewhere that approximately 25–30% of the monitoring budget should be used for data management, assessment and reporting (Watson & Novelly 2004).

Table 3-3 Average estimates of the total number of person hours and costs per sampling location for implementing the bird field surveys, based on a pilot study (n = 18 locations) implemented on public conservation land and assuming that bird surveys will be carried out independently of the mammal pest and vegetation survey teams. (Labour costs are based on an hourly rate of $30 for all tasks except the field team logistics coordinator costs, which are charged at a rate of $40 per hour; Allen et al. 2009a)

Task	Hours	Cost ($)
Field team logistics/co-ordination	6	240
Pre-field preparation	6	180
Travel to location (and set up plot)	35	1,044
Commute to and around plot	13	380
Field survey	4	114
Wet weather day allowance (30%)	15	461
Field operating costs (incl. travel)		1,500
Data entry	10	300
Total per sampling location	89	$4,219

3.5.6 Data management

Practical considerations include determining how data should be collected and managed (e.g. form design, data handling, computerisation, and analysis) (Thomas & Martin 1996; Sergeant et al. 2012) and what additional information is required (including whether the monitoring work should be integrated with other taxa monitoring initiatives), as such contextual data are often important for interpreting and understanding trends (Gregory 2000; Pereira & Cooper 2006; Lindenmayer & Likens 2010), bearing in mind who will be collecting the data (e.g. volunteers and/or professionals) (Gregory 2000; Snäll et al. 2011; Dickinson et al. 2010; Conrad & Hilchey 2011). Any changes to sampling protocols, datasheets and databases must be clearly documented and rules must be established for managing such changes; this should include an assessment of the impact of such changes on the parameters being reported for each measure.

We recommend that the regional council system is consistent with those being used by DOC (Figure 3-6). We recommend that, rather than investing in in-house skills, regional councils should capitalise on the capabilities and investment in database development, management and analytical skills currently being developed by DOC and Landcare Research.

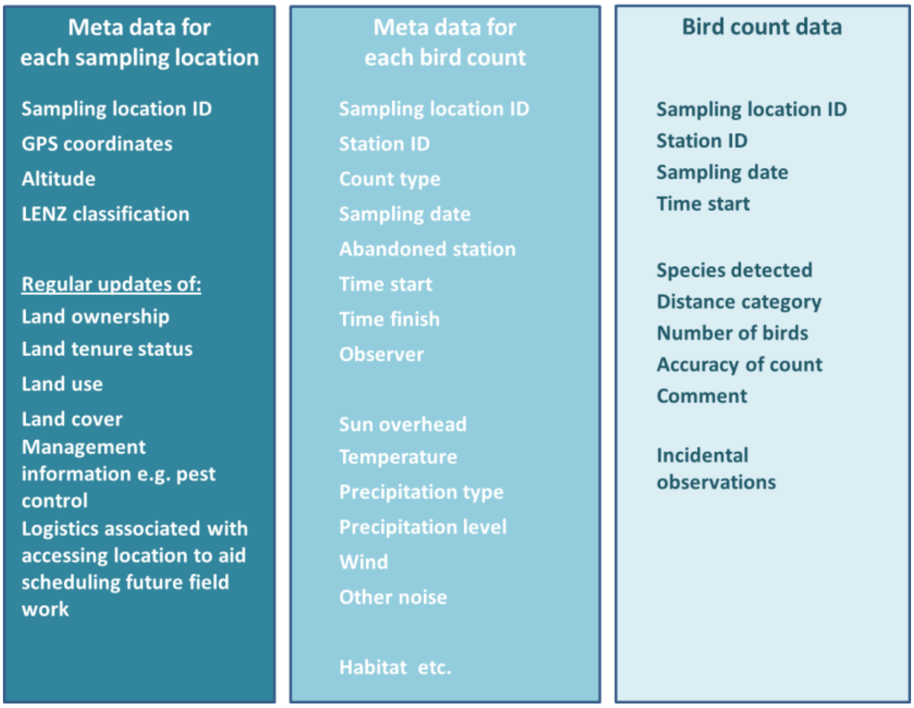


Figure 3-6 Illustration of hierarchical components of the DOC bird-count database for the Biodiversity Monitoring and Reporting System currently under development. We strongly recommend use of a relational database to ensure that the data-entry process is cost-efficient and minimises the risk of data errors.

3.5.7 Reporting indices and formats

To ensure sustained support and interest for the monitoring scheme during the vulnerable period when the benefits are lagging behind the costs (Figure 3-7), it is important to produce some tangible outputs in the short term (Watson & Novelly 2004; Sergeant et al. 2012). The derived benefits from biodiversity monitoring will accumulate over time:

- In the short term, regional councils will be able to report only on static measures of *Avian Representation* status.
- After the first set of remeasurements, the system will report on the status of biodiversity measures relative to baseline measures from the initial survey at regional and national scales, as well as within predominant environments and land-use types.
- In the longer term, the system will report on trends in the biodiversity measures and these could be evaluated against agreed standards or limits.

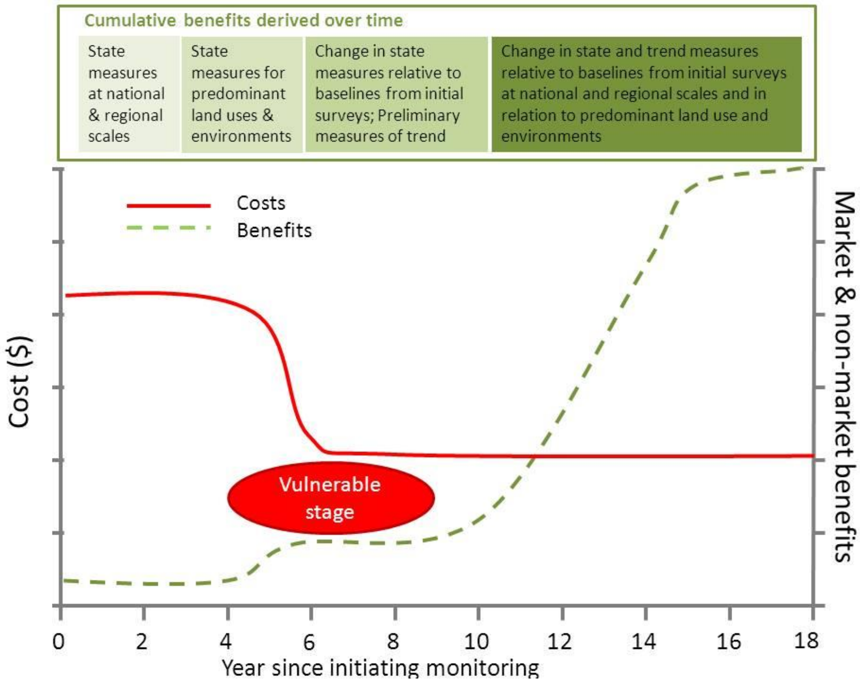


Figure 3-7 Stylised timeline of costs and benefits for biodiversity monitoring, assuming that sampling will start in earnest in the fourth year and the first change data are available in year 6. Start-up costs are higher than ongoing costs, with the vulnerable stage being from year 4 to 8 when the sampling locations are being set up but the change information is not yet available. Benefits increase rapidly as the locations are reassessed, but reach an asymptote at some stage in the future. Figure adapted from Watson & Novelly (2004).

3.5.8 Current status

Information can be presented for all species, different subsets of species or for individual species. Figure 3-8, for example, shows estimates of species richness and occupancy for native and introduced species separately. For the species richness, it shows estimates of the total number of species across all sampling locations and the mean number of species per sampling location. Similar information could be presented for different taxonomic or trophic groups across all species and subsets of native or introduced species (e.g. mean occupancy estimates; see Figure 3-9). Information collected could also be mapped to illustrate distributions of species and community-level metrics (e.g. Figure 3-10).

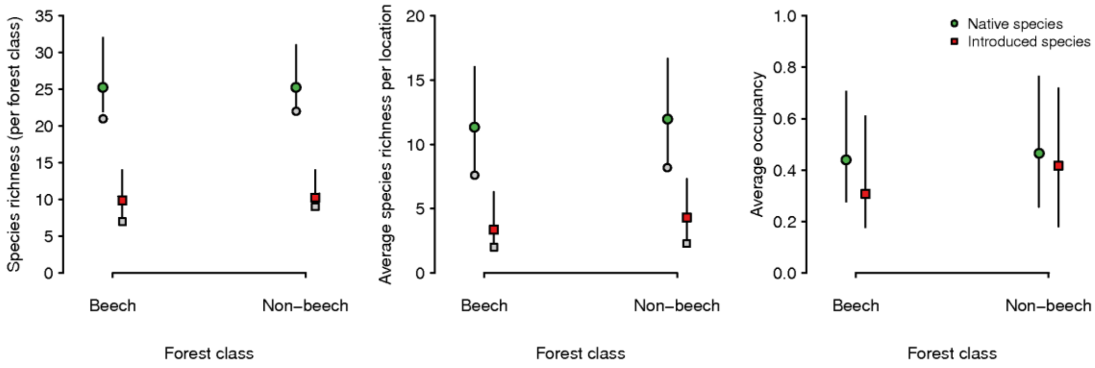


Figure 3-8 Estimates (± 95% Credible Interval) of total species richness, mean species richness and mean species occupancy for native (green circles) and introduced (red squares) species (the observed numbers of species are shown by grey circles or squares) in two forest classes (44 beech and 26 non-beech locations) (MacLeod et al. 2012a). (A credible interval is a Bayesian measure of precision of the estimate similar to a 95% confidence interval.)

(a) Species taxonomy **(b) Feeding guild**

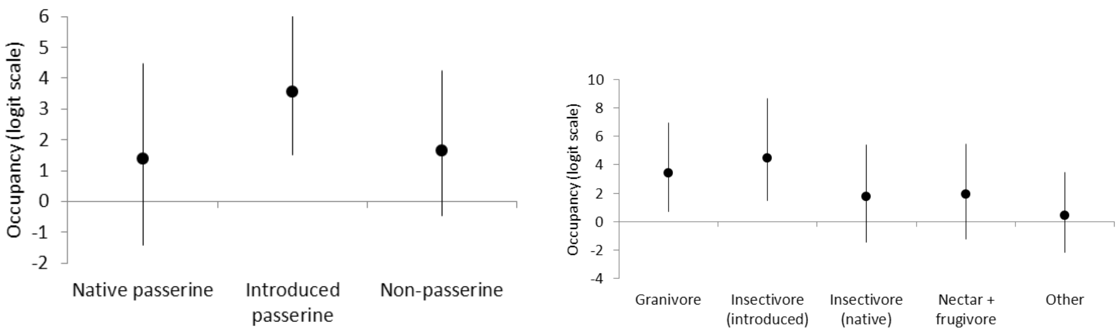


Figure 3-9 Community-level measures of occupancy (means ± 95% Credible Intervals on the logit scale) by (a) species taxonomy and (b) feeding guild for bird communities on the kiwifruit orchards in the Bay of Plenty.

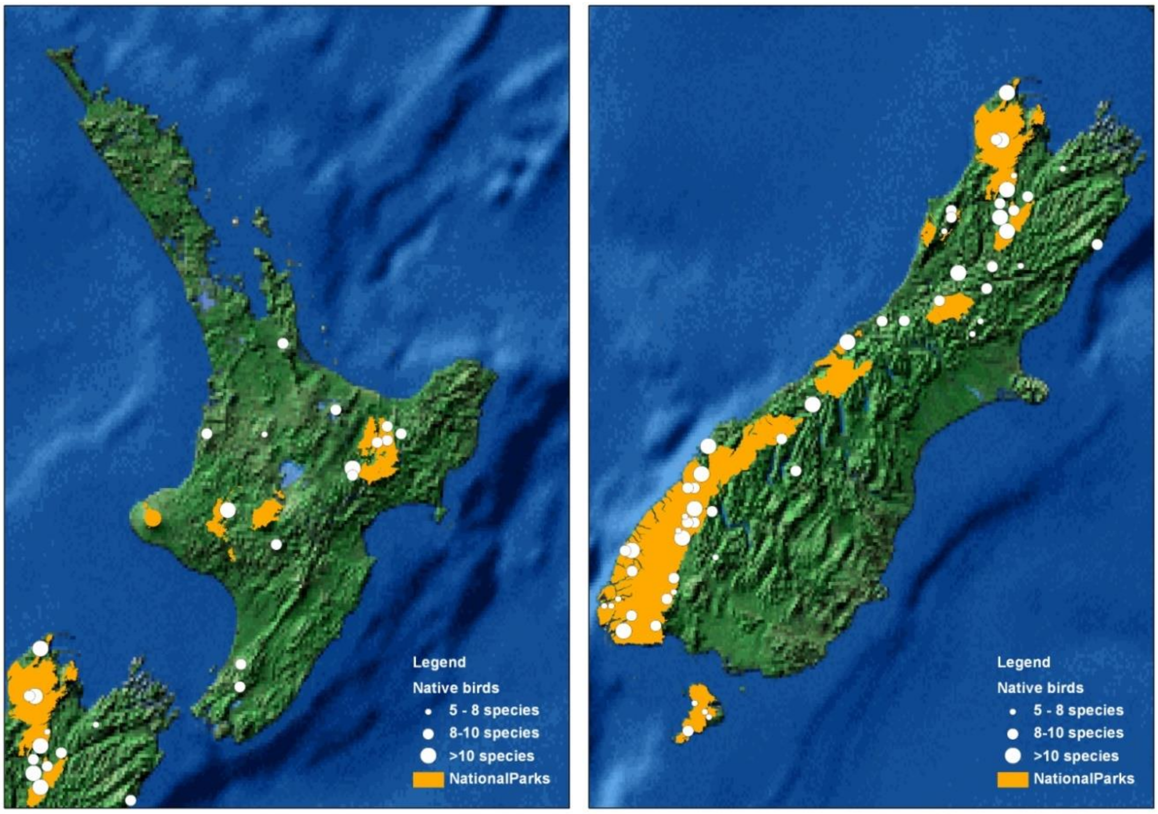


Figure 3-10 Preliminary species richness estimates for native birds for sampling locations in native forests on public conservation land in relation to national parks (MacLeod et al. 2012a).

3.5.9 Change relative to baseline measures

The initial set of measures will provide baseline information with which to compare future measures. Survey data could be used to calculate and map bird distributions at regional and national scales; this would require carefully developed modelling protocols, to ensure inclusion of relevant environmental variables and suitable mechanisms for measuring and illustrating uncertainty associated with derived estimates (e.g. Figure 3-11).

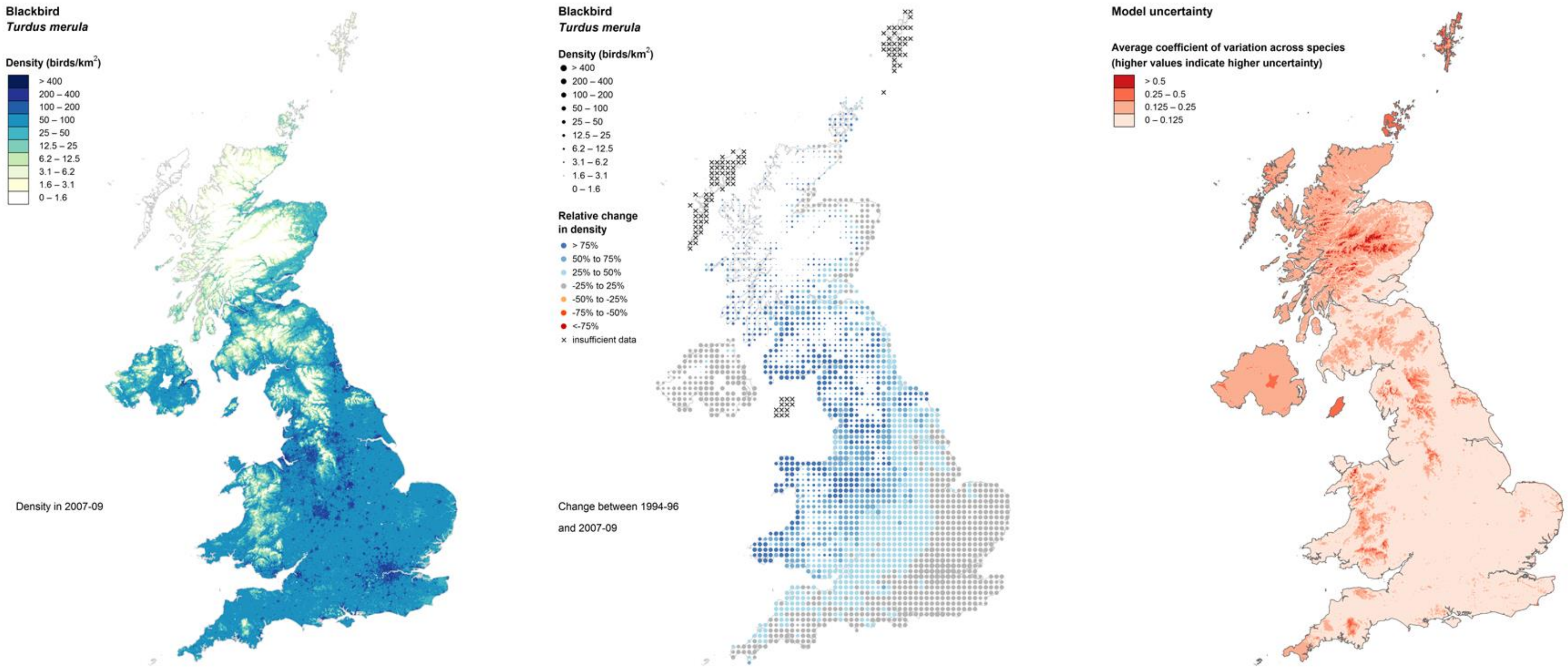


Figure 3-11 Distribution maps could be used to present a range of indicator metrics. Using blackbirds in the UK as an example, these maps show the distribution of current densities, changes in densities between two sampling periods and the uncertainty in the density estimates.

3.5.10 Temporal trends

Trend information could be presented for all species, subsets of species or individual species; for example, tallying of such numbers or proportions of species in various categories and monitoring changes in status of these assemblages over time. Figure 3-12 shows a hypothetical example of trends for all species, as well as subsets of native, endemic and introduced species at the national scale, while Figure 3-13 illustrates trends in forest specialist species relative to non-forest species. Such information could also be presented for different trophic guilds of species.

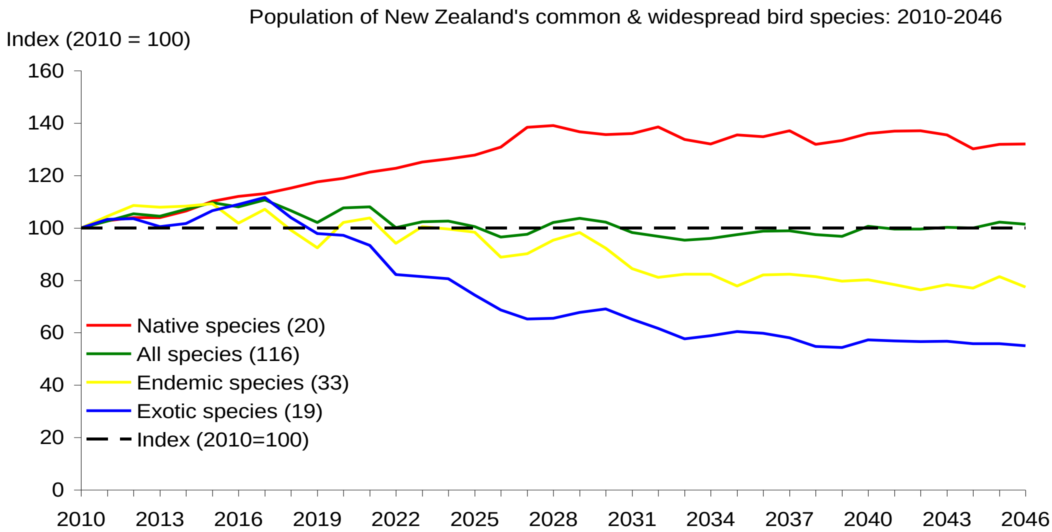


Figure 3-12 Example of overall population trends for different groups of widespread and common birds in New Zealand for the period 2010–2046, where species have been grouped according to their origin. (Based on information reported by the UK's Department for Environment Food and Rural Affairs to report on one of several sustainable development strategy indicators: http://www.defra.gov.uk/ENVIRONMENT/statistics/wildlife/kf/wdkf03.htm)

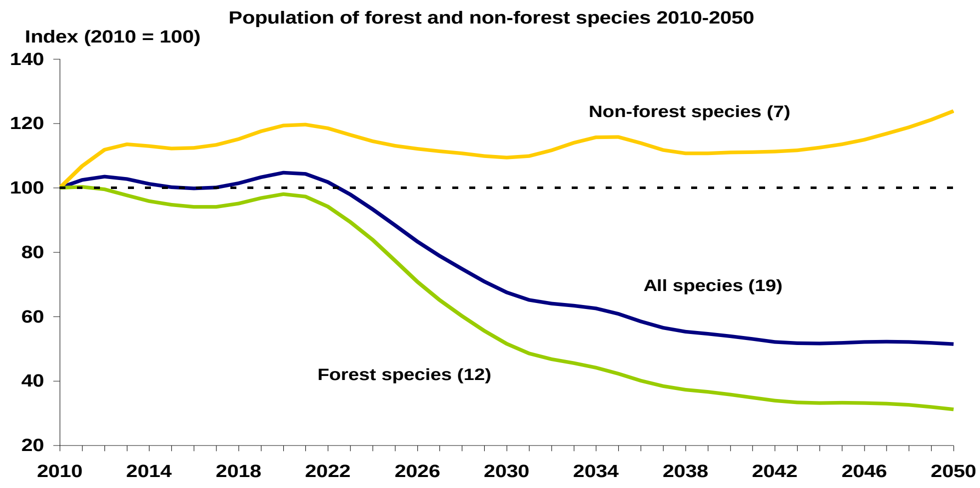


Figure 3-13 Example of overall population trends for different groups of widespread and common birds in New Zealand for the period 2010–2050, where species have been grouped according to whether they are forest specialists or not. (Based on information reported by the UK's Department for Environment Food and Rural Affairs to report on one of several sustainable development strategy indicators: http://www.defra.gov.uk/ENVIRONMENT/statistics/wildlife/kf/wdkf03.htm)

3.6 References

Alldredge MW, Pacifici K, Simons TR, Pollock KH. 2008. A novel field evaluation of the effectiveness of distance and independent observer sampling to estimate aural avian detection probabilities. Journal of Applied Ecology 45:1349–1356.

Alldredge MW, Pollock KH, Simons TR. 2006. Estimating detection probabilities from multiple-observer point counts. The Auk 123:1172–1182.

Alldredge MW, Pollock KH, Simons TR, Collazo JA, Shriner SA. 2007a. Time-of-detection method for estimating abundance from point-count surveys. The Auk 124:653–664.

Alldredge MW, Pollock KH, Simons TR, Shriner SA. 2007b. Multiple-species analysis of point count data: a more parsimonious modelling framework. Journal of Applied Ecology 44:281–290.

Alldredge MW, Simons TR, Pollock KH. 2007c. A field evaluation of distance measurement error in auditory avian point count surveys. The Journal of Wildlife Management 71:2759–2766.

Allen RB, Bellingham PJ, Forsyth DM, MacLeod CJ, Wright EW. 2009a. Implementing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Lincoln, New Zealand: Landcare Research Landcare Research contract report.

Allen R, Wright EF, MacLeod CJ, Bellingham PJ, Forsyth D, Mason N, Gormley A, MacKenzie D, McKay M. 2009b. Designing an inventory and monitoring programme for the Department of Conservation's Natural Heritage Management System. Lincoln, New Zealand: Landcare Research (Landcare Research contract report).

Anderson SH, Kelly D, Ladley JJ, Molloy S, Terry J. 2011. Cascading effects of bird functional extinction reduce pollination and plant density. Science 331:1068–1071.

Bächler E, Liechti F. 2007. On the importance of g(0) for estimating bird population densities with standard distance-sampling: implications from a telemetry study and a literature review. Ibis 149:693–700.

Bairlein F, Norris DR, Nagel R, Bulte M, Voigt CC, Fox JW, Hussell DJT, Schmaljohann H. 2012. Cross-hemisphere migration of a 25 g songbird. Biol. Lett. 8:505–507.

Bart J, Earnst S. 2002. Double sampling to estimate density and population trends in birds. The Auk 119:36–45.

Bibby CJ. 1999. Making the most of birds as environmental indicators. Ostrich 70:81–88.

Bibby CJ, Buckland ST. 1987. Bias of bird census results due to detectability varying with habitat. Acta Oecologica 8:103–112.

Bibby CJ, Burgess ND, Hill DA, Mustoe SH. 2000. Bird Census Techniques. 2nd ed. London: Academic Press.

Blank PJ, Dively GP, Gill DE, Rewa CA. 2011. Bird community response to filter strips in Maryland. Journal of Wildlife Management 75:116–125.

Both C, Visser ME. 2001. Adjustment to climate change is constrained by arrival date in a LD migrant bird. Nature 411:296–298.

Boulinier T, Nichols JD, Sauer JR, Hines JE, Pollock KH. 1998. Estimating species richness: The importance of heterogeneity in species detectability. Ecology 79:1018–1028.

Buckland ST. 1987. On the Variable Circular Plot Method of Estimating Animal Density. Biometrics 43:363–384.

Buckland ST. 2006. Point-transect surveys for songbirds: robust methodologies. The Auk 123:345–357.

Buckland ST, Anderson DR, Burnham KP, Laake JL. 2001. Introduction to Distance Sampling: Estimating Abundance of Biological Populations. Oxford University Press.

Buckland ST, Anderson DR, Burnham KP, Laake JL, Borchers DL, Thomas L, editors. 2004. Advanced Distance Sampling: Estimating abundance of biological populations. Oxford University Press.

Buckland ST, Magurran AE, Green RE, Fewster RM. 2005. Monitoring change in biodiversity through composite indices. Philosophical Transactions of the Royal Society of London B: Biological Sciences 360:243–254.

Buckland ST, Marsden SJ, Green RE. 2008. Estimating bird abundance: making methods work. Bird Conservation International 18:S91–S108.

Buckland ST, Summers RW, Borchers DL, Thomas L. 2006. Point transect sampling with traps or lures. Journal of Applied Ecology 43:377–384.

Bull P, Gaze P, Robertson C. 1985. The atlas of bird distribution in New Zealand. Wellington, New Zealand: Ornithological Society of New Zealand.

Butchart SHM, Walpole M, Collen B, Strien A van, Scharlemann JPW, Almond REA, Baillie JEM, Bomhard B, Brown C, Bruno J, et al. 2010. Global Biodiversity: Indicators of Recent Declines. Science 328:1164–1168.

Conrad CC, Hilchey KG. 2011. A review of citizen science and community-based environmental monitoring: issues and opportunities. Environ Monit Assess 176:273–291.

Costanza R, Norton BG, Haskell BD, editors. 1992. Ecosystem Health: New Goals for Environmental Management. Island Press.

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

Devictor V, Whittaker RJ, Beltrame C. 2010. Beyond scarcity: citizen science programmes as useful tools for conservation biogeography. Diversity and Distributions 16:354–362.

Dickinson JL, Zuckerberg B, Bonter DN. 2010. Citizen science as an ecological research tool: challenges and benefits. Annual Review of Ecology, Evolution, and Systematics 41:149–172.

DOC (Department of Conservation). 2012. DOCDM-828397 Tier 1 monitoring (201112) MASTER protocol booklet. Wellington, N.Z.: Department of Conservation.

Dorazio RM, Kéry M, Royle JA, Plattner M. 2010. Models for inference in dynamic metacommunity systems. Ecology 91:2466–2475.

Eaton MA, Brown AF, Noble DG, Musgrove AJ, Hearn RD, Aebischer NJ, Gibbons DW, Evans A, Gregory RD. 2009. Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and Isle of Man. British Birds 102:296–341.

Efford MG, Dawson DK. 2012. Occupancy in continuous habitat. Ecosphere 3(4): 32. http://dx.doi:10.1111/j.1365-2664.2008.01545.x

Elphick CS. 2008. How you count counts: the importance of methods research in applied ecology. Journal of Applied Ecology 45:1313–1320.

Emlen JT. 1971. Population densities of birds derived from transect counts. The Auk 88:323–342.

Emlen JT. 1977. Estimating breeding season bird densities from transect counts. The Auk 94:455–468.

Farnsworth GL, Pollock KH, Nichols JD, Simons TR, Hines JE, Sauer JR. 2002. A removal model for estimating detection probabilities from point-count surveys. The Auk 119:414–425.

Fewster RM, Buckland ST, Siriwardena GM, Baillie SR, Wilson JD. 2000. Analysis of Population Trends for Farmland Birds Using Generalized Additive Models. Ecology 81:1970–1984.

Field SA, O'Connor PJ, Tyre AJ, Possingham HP. 2007. Making monitoring meaningful. Austral Ecology 32:485–491.

Field SA, Tyre AJ, Possingham HP. 2005. Optimizing allocation of monitoring effort under economic and observational constraints. Journal of Wildlife Management 69:473–482.

Fitzgerald N, Innes J. 2013. Hamilton City biennial bird counts: 2004–2012. Lincoln, New Zealand: Landcare Research (Landcare Research contract report).

Fletcher RJ, Hutto RL. 2006. Estimating detection probablities of river birds using double surveys. The Auk 123:695–707.

Furness RW, Greenwood JJD, editors. 1993. Birds as Monitors of Environmental Change. London: Chapman & Hall.

Gotelli NJ, Colwell RK. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters 4:379–391.

Gottschalk TK, Huettmann F. 2011. Comparison of distance sampling and territory mapping methods for birds in four different habitats. J Ornithol 152:421–429.

Gregory RD. 2000. Development of breeding bird monitoring in the United Kingdom and adopting its principles elsewhere. Ringing 22:35–44.

Guillera-Arroita G, Ridout MS, Morgan BJT. 2010. Design of occupancy studies with imperfect detection. Methods in Ecology and Evolution 1:131–139.

Haila Y, Nicholls AO, Hanski IK, Raivio S. 1996. Stochasticity in bird habitat selection: year-to-year changes in territory locations in a boreal forest bird assemblage. Oikos 76:536–552.

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

Hoare JM, Monks A, O'Donnell CFJ. 2012. Can correlated population trends among forest bird species be predicted by similarity in traits? Wildl. Res. 39:469–477.

Holdaway RJ, Wiser SK, Williams PA. 2012. Status assessment of New Zealand's naturally uncommon ecosystems. Conservation Biology 26:619–629.

Hunt L, McCusker K, MacLeod CJ, Moller H, Reid J, Barr T, Lambert S, Rosin C, le Quellec I, Manhire J. 2014. Framework and KPIs for "The New Zealand Sustainability Dashboard": reflecting New Zealand's economic, social, environmental and management values. ARGOS (Agricultural Research Group on Sustainability) (NZ Sustainability Dashboard Research Report).

Hurst JM, Allen RB. 2007. The Recce method for describing New Zealand vegetation – field protocols. Lincoln, New Zealand: Manaaki Whenua-Landcare Research.

IUCN Standards and Petitions Working Group Subcommittee. 2008. Guidelines for using the IUCN Red List categories and criteria. Version 7. Gland, Switzerland: IUCN.

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

Jones JPG, Asner GP, Butchart SHM, Karanth KU. 2013. The “why”, “what” and “how” of monitoring for conservation. In: Macdonald D, Willis KJ, editors. Key Topics in Conservation Biology 2. John Wiley & Sons. p. 327–343. [accessed 2016 Jan 25]. http://onlinelibrary.wiley.com/doi/10.1002/9781118520178.ch18/summary

Jones JPG, Collen B, Atkinson G, Baxter PWJ, Bubb P, Illian JB, Katzner TE, Keane A, Loh J, McDonald-Madden E, et al. 2011. The why, what, and how of global biodiversity indicators beyond the 2010 target. Conserv. Biol. 25:450–457.

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.

LaDeau SL, Kilpatrick AM, Marra PP. 2007. West Nile virus emergence and large-scale declines of North American bird populations. Nature 447:710–713.

Leathwick JR, Wilson G, Rutledge D, Wardle P, Morgan F, Johnston K, McLeod M, Kirkpatrick R. 2003. Land Environments of New Zealand. Auckland, New Zealand: David Bateman. [accessed 2016 Jan 25]. http://scholar.google.com/scholar?cluster=3752122785964396616&hl=en&oi=scholarr

Lee WG, Allen RB. 2011. Recommended monitoring framework for regional councils assessing biodiversity outcomes in terrestrial ecosystems. Landcare Research Landcare Research contract report for the Regional Council Biodiversity Forum Technical Group.

Lee W, McGlone M, Wright EF. 2005. Biodiversity inventory and monitoring a review of national and international systems and a proposed framework for future biodiversity monitoring by the Department of Conservation. Wellington, N.Z.: Manaaki Whenua-Landcare Research New Zealand Ltd. [accessed 2016 Jan 25]. http://www.landcareresearch.co.nz/research/obi/public/biodiv_inventory_monitoring.pdf#search=

Lewin-Koh N, Bivand R, Pebesma E, Archer E, Dray S, Forrest D, Giraudoux P, Golicher D, Gomez-Rubio V, Hausmann P, et al. 2008. maptools: tools for reading and handling spatial objects.

Lindenmayer DB, Gibbons P, Bourke M, Burgman M, Dickman CR, Ferrier S, Fitzsimons J, Freudenberger D, Garnett ST, Groves C, et al. 2012. Improving biodiversity monitoring. Austral Ecology 37:285–294.

Lindenmayer DB, Likens GE. 2010. The science and application of ecological monitoring. Biological Conservation 143:1317–1328.

Link WA, Sauer JR. 1998. Estimating population change from count data: application to the North American breeding bird survey. Ecological Applications 8:258–268.

MacKenzie DI. 2005. What are the issues with presence-absence data for wildlife managers? The Journal of Wildlife Management 69:849–860.

MacKenzie DI, Nichols JD, Hines JE, Knutson MG, Franklin AB. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200–2207.

MacKenzie DI, Nichols JD, Lachman GB, Droege S, Andrew Royle J, Langtimm CA. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248–2255.

Mackenzie DI, Royle JA. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42:1105–1114.

MacLeod CJ, Affeld K, Allen RB, Bellingham PJ, Forsyth DM, Gormley AM, Holdaway RJ, Richardson SJ, Wiser SK. 2012a. Department of Conservation biodiversity indicators: 2012 assessment. Landcare Research.

MacLeod CJ, Bellingham PJ, Gormley AM, Lyver P, Overton J, Fitzgerald G, Ombler F, Hansen P, Maseyk F, Dickison M, et al. 2013. Building trustworthy biodiversity measures – using birds as a proof-of-concept. Research proposal prepared for the Ministry of Business, Innovation and Employment's Terrestrial Biodiversity Sandpit Round 2013. New Zealand: Landcare Research.

MacLeod CJ, Blackwell G, Benge J. 2012b. Reduced pesticide toxicity and increased woody vegetation cover account for enhanced native bird densities in organic orchards. Journal of Applied Ecology 49:652–660.

MacLeod CJ, Blackwell G, Weller F, Moller H. 2012c. Designing a bird monitoring scheme for New Zealand's agricultural sectors. New Zealand Journal of Ecology 36:312–323.

MacLeod CJ, Gormley AM, Thomson FJ, Bellingham PJ. 2012d. Designing a biodiversity monitoring and reporting system for Greater Wellington Regional Council. Lincoln, New Zealand: Landcare Research.

MacLeod CJ, Greene T, MacKenzie DI, Allen R. 2012e. Monitoring widespread and common bird species on New Zealand's conservation lands: a pilot study. New Zealand Journal of Ecology 36:300–311.

MacLeod CJ, Moller H. 2013. Environmental monitoring for sustainable land management in New Zealand's production landscapes. The New Zealand Sustainability Dashboard Research Report. ARGOS (Agricultural Research Group on Sustainability).

MacLeod CJ, Tinkler G, Gormley AM, Spurr EB. 2012f. Measuring occupancy for an iconic bird species in urban parks. New Zealand Journal of Ecology 36:398–407.

Magurran AE, Baillie SR, Buckland ST, Dick JM, Elston DA, Scott EM, Smith RI, Somerfield PJ, Watt AD. 2010. Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. Trends Ecol. Evol. (Amst.) 25:574–582.

Manhire J, Moller H, Barber A, Saunders C, MacLeod C, Rosin C, Lucock D, Post E, Ombler F, Campbell H, et al. 2012. The New Zealand Sustainability Dashboard: unified monitoring and learning for sustainable agriculture in New Zealand. ARGOS (Agriculture Research Group on Sustainability) (ARGOS working paper).

MfE (Ministry for the Environement). 2005. Measuring carbon emissions from land-use change and forestry. The New Zealand Land-Use and Carbon Analysis System. Wellington, New Zealand: Ministry for the Environment.

Moffat M, Minot EO. 1994. Distribution and abundance of forest birds in the Ruamahanga Ecological Area, North Island, New Zealand. New Zealand Journal of Zoology 21:135–150.

Monks A, MacLeod CJ. 2013. Evaluating the ARGOS soil monitoring scheme on kiwifruit orchards. New Zealand: Landcare Research Report for the Agricultural Research Group on Sustainability.

Moore JE, Scheiman DM, Swihart RK. 2004. Field comparison of removal and modified double-observer modeling for estimating detectability and abundance of birds. The Auk 121:865–876.

Newson SE, Evans KL, Noble DG, Greenwood JJD, Gaston KJ. 2008. Use of distance sampling to improve estimates of national population sizes for common and widespread breeding birds in the UK. Journal of Applied Ecology 45:1330–1338.

Newson SE, Woodburn RJW, Noble DG, Baillie SR, Gregory RD. 2005. Evaluating the Breeding Bird Survey for producing national population size and density estimates. Bird Study 52:42–54.

Newton I. 1998. Population Limitation in Birds. Academic Press.

Nichols JD, Bailey LL, O'Connell Jr. AF, Talancy NW, Campbell Grant EH, Gilbert AT, Annand EM, Husband TP, Hines JE. 2008. Multi-scale occupancy estimation and modelling using multiple detection methods. Journal of Applied Ecology 45:1321–1329.

Nichols JD, Boulinier T, Hines JE, Pollock KH, Sauer JR. 1998. Inference methods for spatial variation in species richness and community composition when not all species are detected. Conservation Biology 12:1390–1398.

Nichols JD, Hines JE, Sauer JR, Fallon FW, Fallon JE, Heglund PJ. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117:393–408.

Nichols JD, Thomas L, Conn PB. 2009. Inferences about landbird abundance from count data: recent advances and future directions. In: Thomson DL, Cooch EG, Conroy MJ, editors. Modeling demographic processes in marked populations. Springer US. (Environmental and Ecological Statistics). p. 201–235. [accessed 2016 Jan 25]. http://link.springer.com/chapter/10.1007/978-0-387-78151-8_9

Noon BR, Bailey LL, Sisk TD, McKelvey KS. 2012. Efficient species-level monitoring at the landscape scale. Conserv. Biol. 26:432–441.

Pereira HM, Cooper HD. 2006. Towards the global monitoring of biodiversity change. Trends in Ecology & Evolution 21:123–129.

Reidy JL, Thompson III F, Bailey JW. 2011. Comparison of methods for estimating density of forest songbirds from point counts. The Journal of Wildlife Management 75:558–568.

Robertson C, Hyvönen P, Fraser M, Pickard C. 2007. Atlas of bird distribution in New Zealand 1999–2004. Wellington, New Zealand: Ornithological Society of New Zealand.

Rodríguez JP, Rodríguez-Clark KM, Baillie JEM, Ash N, Benson J, Boucher T, Brown C, Burgess ND, Collen B, Jennings M, et al. 2011. Establishing IUCN Red List Criteria for Threatened Ecosystems. Conservation Biology 25:21–29.

Rosenstock SS, Anderson DR, Giesen KM, Leukering T, Carter MF, Thompson III F. 2002. Landbird counting techniques: current practices and an alternative. The Auk 119:46–53.

Schmeller D, Henle K, Loyau A, Besnard A, Henry P-Y. 2012. Bird-monitoring in Europe – a first overview of practices, motivations and aims. Nature Conservation 2:41–57.

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

Sergeant CJ, Moynahan BJ, Johnson WF. 2012. Practical advice for implementing long-term ecosystem monitoring. Journal of Applied Ecology 49:969–973.

Simons TR, Pollock KH, Wettroth JM, Alldredge MW, Pacifici K, Brewster J. 2009. Sources of measurement error, misclassification error, and bias in auditory avian point count data. In: Thomson DL, Cooch EG, Conroy MJ, editors. Modeling Demographic Processes In Marked Populations. Springer US. (Environmental and Ecological Statistics). p. 237–254. [accessed 2016 Jan 25]. http://link.springer.com/chapter/10.1007/978-0-387-78151-8_10

Siriwardena GM, Baillie SR, Buckland ST, Fewster RM, Marchant JH, Wilson JD. 1998. Trends in the abundance of farmland birds: a quantitative comparison of smoothed Common Birds Census indices. Journal of Applied Ecology 35:24–43.

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

Spurr E. 2012. New Zealand Garden Bird Survey – analysis of the first 4 years. New Zealand Journal of Ecology 36:287–299.

Studeny AC, Buckland ST, Illian JB, Johnston A, Magurran AE. 2011. Goodness-of-fit measures of evenness: a new tool for exploring changes in community structure. Ecosphere 2:1–19.

Sullivan J. 2012. Recording birds in real time: a convenient method for frequent bird recording. New Zealand Journal of Ecology 36:416–424.

Terralink 2004.New Zealand Land Cover Database version 2 (LCDB2). Wellington, New Zealand, Terralink International.

Thomas L, Buckland ST, Rexstad EA, Laake JL, Strindberg S, Hedley SL, Bishop JRB, Marques TA, Burnham KP. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5–14.

Thomas L, Martin K. 1996. The importance of analysis method for breeding bird survey population trend estimates. Conservation Biology 10:479–490.

Thompson WL. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. The Auk 119:18–25.

Tuomisto H. 2012. An updated consumer's guide to evenness and related indices. Oikos 121:1203–1218.

Urquhart NS, Paulsen SG, Larsen DP. 1998. Monitoring for policy-relevant regional trends over time. Ecological Applications 8:246–257.

Voříšek P, Klvaňová A, Wotton S, Gregory RD, editors. 2008. A best practice guide for wild bird monitoring schemes. 1st ed. Prague: CSO/RSPB.

Watson I, Novelly P. 2004. Making the biodiversity monitoring system sustainable: Design issues for large-scale monitoring systems. Austral Ecology 29:16–30.

Williams PA, Wiser S, Clarkson B, Stanley MC. 2007. New Zealand's historically rare terrestrial ecosystems set in a physical and physiognomic framework. New Zealand Journal of Ecology 31:119–128.

Wilson JD, Evans AD, Grice PV. 2010. Bird conservation and agriculture: a pivotal moment? Ibis 152:176–179.

Yoccoz NG, Nichols JD, Boulinier T. 2001. Monitoring of biological diversity in space and time. Trends in Ecology & Evolution 16:446–453.

Zipkin EF, Andrew Royle J, Dawson DK, Bates S. 2010. Multi-species occurrence models to evaluate the effects of conservation and management actions. Biological Conservation 143:479–484.

Appendix 3-1 – Skills and logistical requirements for bird count methods

Table A3-1-1 Skill and logistical requirements for three unadjusted bird count methods, and the monitoring approaches (what is measured; **Figure 3-1**) that each method is best suited for as a result.

Components	Requirement	Territory mapping	Point counts	Transect counts
Field skills	Species identification	Basic	Moderate to complex	Moderate to complex
	Data recording	Complex	Basic	Basic
	Method application	Basic	Basic	Moderate
Field logistics	Equipment	Basic	Basic	Basic
	Labour	High	Low	Moderate
	Efficiency	Low	High	Moderate
Data processing	Skills	Basic	Basic	Basic
	Software	N/A	NA	NA
	Labour cost	Moderate	Low	Moderate
	Area sampled	Yes	Yes (for bounded counts)	Yes (for strip counts)
Monitoring approach suited		Targeted surveys Experimental studies	All	All apart from unstructured surveillance
Applied examples		Haila et al. 1996; Siriwardena et al. 1998; Gregory 2000; Gottschalk & Huettmann 2011	Link & Sauer 1998; LaDeau et al. 2007	Blank et al. 2011

Table A3-1-2 Skill and logistical requirements for adjusted bird count methods, and the monitoring approaches (what is measured; **Figure 3-1**) best suited as a result

Component	Requirement	Distance sampling				Multiple observer point counts	Time-of-detection point counts
		Line transects	Point or binomial point transects	Cue point counts	Lure point transects	Independent or dependent	Multi-observer, removal or time-interval
Field skills	Species identification	Complex	Complex	Complex	Moderate, as typically focus on specific species	Complex	Complex
	Data recording	Basic	Moderate	Moderate	Moderate	Complex	Complex
	Method application	Complex	Moderate	Complex	Moderate	Complex	Complex
Field logistics	Equipment	Moderate	Moderate	Moderate	Moderate	Basic	Basic
	Labour	Moderate	Moderate	Moderate	High	High	Moderate
	Efficiency	Very high	High	High	Moderate	Moderate	Moderate
Data processing	Skills	Moderate to high	Moderate to high	Moderate to high	Moderate to high	Moderate to high	Moderate to high
	Software	Distance	Distance	Distance	Distance	MARK	MARK
	Labour cost	Moderate	Moderate	Moderate	Moderate	High	High
	Area sampled	Yes	Yes (maximum distance to cue for binomial)	Yes	Yes	Recommended	Recommended
Monitoring approach suited		All apart from unstructured surveillance	All apart from unstructured surveillance	Targeted surveys and experimental studies	Targeted surveys and experimental studies	All apart from unstructured surveillance	Targeted surveys and experimental studies
Applied examples		Gregory 2000; Newson et al. 2005, 2008; Gottschalk & Huettmann 2011	Gregory 2000; Kissling & Garton 2006; Alldredge et al. 2007c; Moffat & Minot 1994	Buckland 2006	Buckland et al. 2006	Moore et al. 2004; Fletcher & Hutto 2006; Kissling & Garton 2006; Alldredge et al. 2007b Blank et al. 2011	Moore et al. 2004; Alldredge et al. 2007b; Reidy et al. 2011

Appendix 3-2 – Extending the DOC BMRS sampling grid across regions

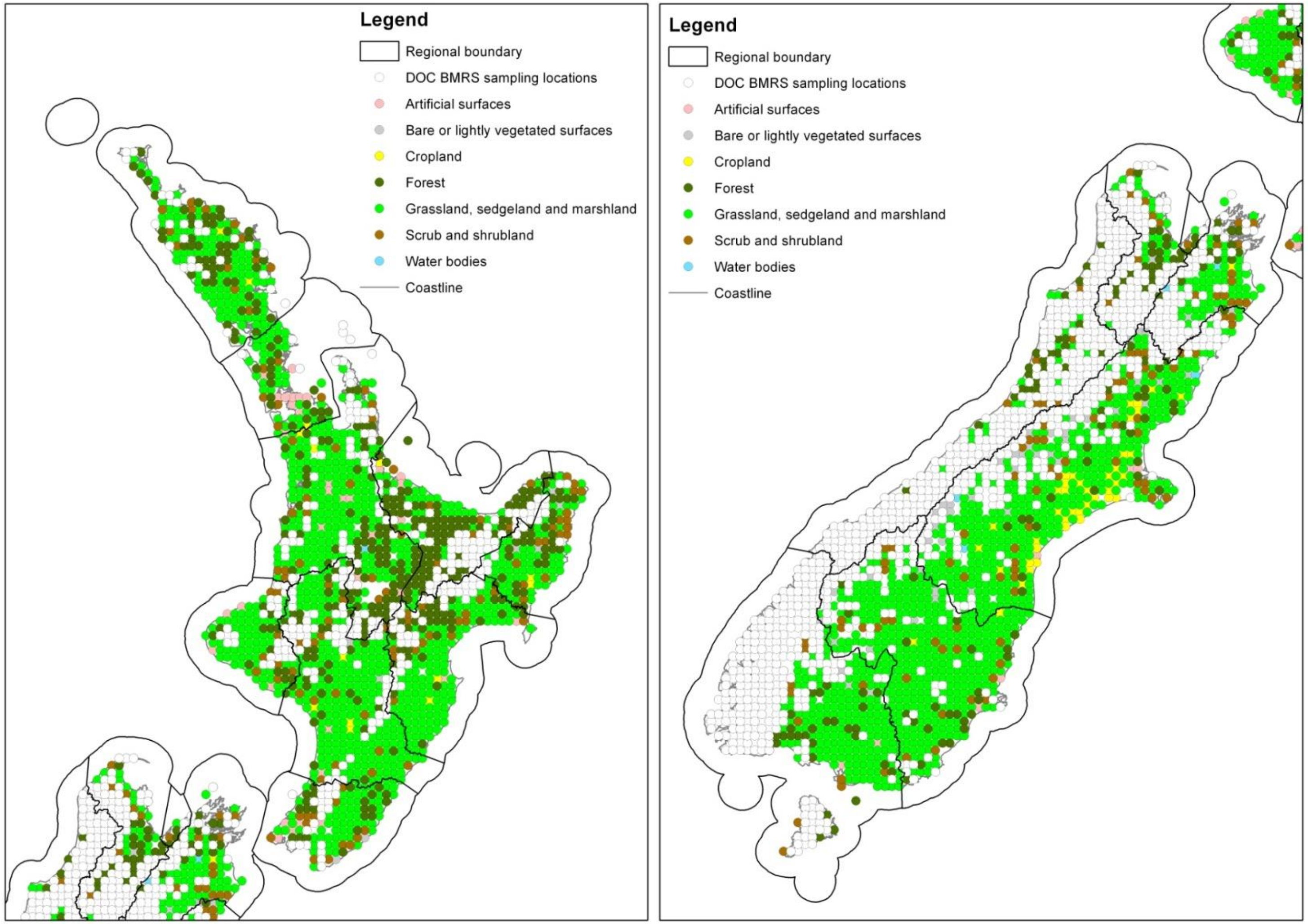


Figure A3-2-1 Sampling locations on the 8 × 8 km grid in relation to the regional council boundaries and landcover classification of sampling locations (see table below; excludes locations with slope >65º; open circles show the sampling locations covered by the DOC BMRS).

Table A3-2-1 Number and/or percentage of sampling locations on the 8 × 8 m grid within each region, sampled by the DOC BMRS or not, having steep slopes (estimated using LENZ; Leathwick et al. 2003), and within different landcover classes (based on first order land cover classes from the New Zealand Land Cover Database, LCDB2; Terralink (2004)).

Region	No. sampling locations			Percentage sampling locations									
	Total	DOC BMRS	Currently not sampled	DOC BMRS	Currently not sampled	Slope >45°	Artificial surfaces	Bare or lightly vegetated surfaces	Cropland	Forest	Grassland, sedgeland & marshland	Scrub & shrubland	Water bodies
Auckland	78	6	72	8	92	0	13	0	1	23	49	14	0
Bay of Plenty	194	60	134	31	69	2	2	0	<1	73	19	6	0
Canterbury	692	169	523	24	76	1	<1	12	6	10	63	9	<1
Gisborne	130	15	115	12	88	1	0	3	2	33	48	15	0
Hawke’s Bay	216	39	177	18	82	0	<1	0	<1	30	57	11	0
Manawatū–Wanganui	349	61	288	17	83	0	<1	<1	1	23	67	8	0
Marlborough	153	73	80	48	52	3	0	10	<1	27	48	12	2
Nelson City	7	2	5	29	71	0	0	0	0	71	14	14	0
Northland	202	27	175	13	87	<1	0	1	1	36	53	9	0
Otago	480	87	393	18	82	1	<1	5	<1	10	78	7	0
Southland	478	260	218	54	46	7	<1	4	0	39	49	8	<1
Taranaki	114	26	88	23	77	0	4	0	0	33	56	8	0
Tasman	151	102	49	68	32	2	0	4	0	70	19	8	0
Waikato	369	64	305	17	83	0	2	<1	<1	35	55	7	<1
Wellington	125	23	102	18	82	1	4	2	0	31	49	14	0
Westland	346	297	49	86	14	4	0	7	0	65	15	12	0
Total no. of locations	4084	1311	2773			76	42	180	56	1303	2126	367	10
Total % of locations				32	68	<2	1.0	4.4	1.4	31.9	52.1	9.0	0.2

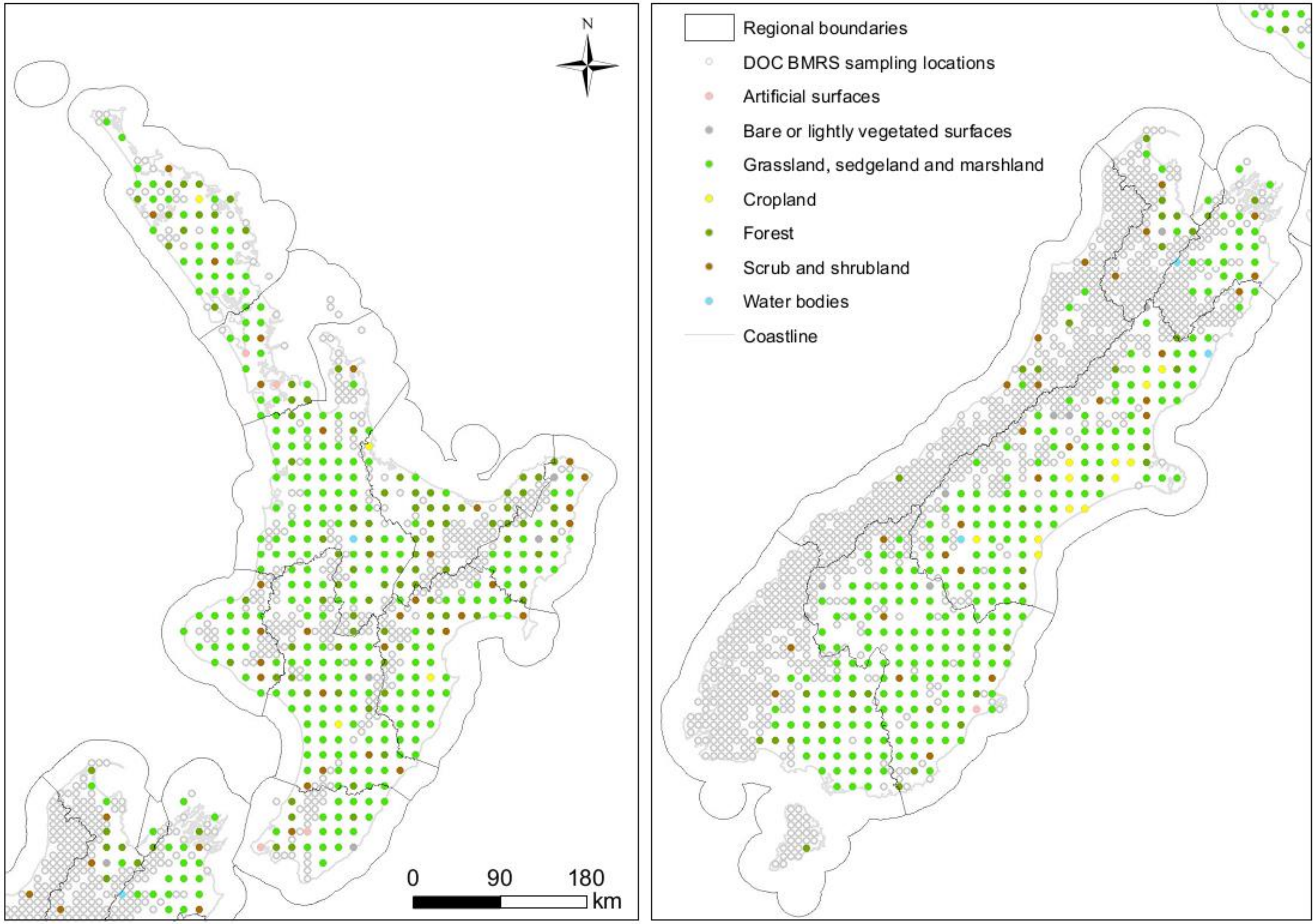


Figure A3-2-2 Sampling locations on a 16 × 16 km grid in relation to the regional council boundaries and landcover classification of sampling locations.

TableA3-2-2 Number and/or percentage of sampling locations within each region based on a 16 × 16 km grid, sampled by the DOC BMRS or not, have steep slopes (estimated using LENZ; Leathwick et al. 2003), and within different landcover classes (based on first-order land cover classes from the New Zealand Land Cover Database, LCDB2; Terralink (2004))

Region	No. sampling locations			Percentage sampling locations									
	Total	DOC BMRS	Currently not sampled	DOC BMRS	Currently not sampled	Slope >45°	Artificial surfaces	Bare or lightly vegetated surfaces	Cropland	Forest	Grassland, sedgeland & marshland	Scrub & shrubland	Water bodies
Auckland	18	0	18	0	100	0.0	11	0	0	17	61	11	0
Bay of Plenty	49	17	32	35	65	4.1	0	0	2	84	10	4	0
Canterbury	177	47	130	27	73	0.6	0	10	7	10	63	10	1
Gisborne	32	2	30	6	94	0.0	0	6	0	31	50	13	0
Hawke's Bay	55	7	48	13	87	0.0	0	0	2	29	55	15	0
Manawatū-Wanganui	86	14	72	16	84	0.0	0	1	1	23	65	9	0
Marlborough	38	17	21	45	55	5.3	0	13	0	13	63	8	3
Nelson City	2	0	2	0	100	0.0	0	0	0	50	50	0	0
Northland	50	7	43	14	86	0.0	0	0	2	36	54	8	0
Otago	120	18	102	15	85	0.0	1	4	0	10	81	4	0
Southland	116	65	51	56	44	8.6	0	2	0	41	48	8	1
Taranaki	29	6	23	21	79	0.0	0	0	0	31	55	14	0
Tasman	36	23	13	64	36	0.0	0	6	0	69	11	14	0
Waikato	96	19	77	20	80	0.0	0	1	0	34	59	4	1
Wellington	32	7	25	22	78	0.0	6	3	0	34	50	6	0
Westland	83	72	11	87	13	3.6	0	8	0	66	10	16	0
Total no. of locations	1019	321	698			18	5	44	16	324	535	90	5
Total percentage of locations				32	68	1.8	0.5	4.3	1.6	31.8	52.5	8.8	0.5

Appendix 3-3 – Unadjusted bird count methods

Table A3-3-1 Methods considerations for unadjusted bird counts (i.e. counts that do not account for potential variation in detectability).

Method	Species suitability	Habitat suitability	Key assumptions	Sources of bias	References	
					Methods	Validation
Territory mapping	Territorial species (but not semi-colonial, birds that only sing for brief periods, or non-standard mating systems)	All habitats but impractical at large scales	To decide whether a territory will be assigned for counting, a fixed ratio of registrations of a species to the number of effective visits for that species is used (e.g. ≥2 registrations for ≤8 visits or ≥3 registrations for ≥9 visits)	Edge and highly dynamic territories create problems. Density estimates vary depending on the registrations-to-visits ratio used to determine territories and minimum distance at which an observation is assumed to belong to a territory. Setting a fixed ratio for determining a territory does not allow for variation in detection probabilities among different habitat types and species	Bibby et al. 2000; Gottschalk & Huettman 2011	
Point counts (can be bounded or unbounded)	Suitable for multi-species surveys, particularly when cues mostly aural	All habitats; useful for dense habitats or difficult terrain	No bird is knowingly counted twice	Does not allow for variation in detection probabilities among different habitat types, species and seasons	Dawson & Bull 1975; Johnson 2008	
Transect counts (can be strip or unbounded)	Not suitable for silent or inactive species	Unsuitable for small, isolated blocks of distinctive habitat	All birds within strip transect are observed, where the strip width is set narrow enough to detect all cues	Temporary movement of boundary-line birds into the relatively narrow census strip. Birds are missed or distances are misjudged. Conspicuousness varies markedly from species to species; hence, each species must be dealt with as a separate entity	Emlen 1971, 1977	

Appendix 3-4 – Adjusted bird count methods

Table A3-4-1 Methods considerations for adjusted bird counts (i.e. counts that attempt to account for potential variation in detectability).

Method	Species suitability	Habitat suitability	Key assumptions	Sources of bias	References	
					Method	Validation
Distance sampling (line transects)	Suits mobile, conspicuous species and those that flush. Difficult for multi-species surveys if observer swamped	Open habitat only	Birds on line are certain to be detected; birds are detected at their initial location; distance measures are exact; group sizes are recorded without error	Flushed birds can move either beyond the range of detectability, which can result in negative bias, or within the area of detectability, which can result in double-counting of birds	Buckland et al. 2001, 2004, 2008; Thomas et al. 2010	Bächler & Liechti 2007; Alldredge et al. 2007c, 2008
Distance sampling (point or binomial point transects)	Suitable for multi-species surveys. Also for cryptic and skulking species. Not suited to species that flee from the observer	All habitats; less useful for dense habitats or difficult terrain	Point transects: birds on point (or within radius *r* for binomial) are certain to be detected; birds are detected at their initial location; distance measures are exact; group sizes are recorded without error.	Potential overestimation; with longer count periods, there is increased potential for positive bias owing to random movement of birds, but shorter counts result in fewer detections. Flushed birds can move either beyond the range of detectability, which can result in negative bias, or within the area of detectability, which can result in double-counting of birds.	Buckland 1987; Bibby & Buckland 1987; Buckland et al. 2001, 2004, 2008; Thomas et al. 2010.	Buckland 2006, Alldredge et al. 2007c, 2008
Distance sampling (cue point counts)	Calling species that move around during typical duration of point count. Observer swamping can be problem as distance to all cues is recorded	All habitats; particularly useful for dense habitats or difficult terrain	As for point and line transects, but do not need to distinguish between individual birds.	Over-dispersed data may be an issue. Need a representative sample of birds from separate fieldwork to estimate cue rate.	Buckland et al. 2001, 2004, 2008; Thomas et al. 2010	

Method	Species suitability	Habitat suitability	Key assumptions	Sources of bias	References	
					Method	Validation
Distance sampling (lure point transects)	Species that are rare or difficult to detect when present or probability of detection decreases sharply away from the point.	All habitats; particularly useful for dense habitats or difficult terrain	Does not assume that birds at the point are detected with certainty; uses experimental data to estimate detection function taking into account whether a random sample of birds responds to a lure or not. Care needed selecting appropriate truncation distance	Edge effects possible. If birds occur in flocks, it is possible only some individuals respond to lure. Guidelines for accounting for these are provided	Buckland et al. 2006	
Multiple-observer point counts (independent or dependent)	Species with reasonable detection probabilities (e.g. >0.4)	All habitats; less useful for dense habitats or difficult terrain	Detection of a bird by primary and secondary observers is independent; observers observe the same individuals; an observer's detection probability is the same regardless of whether they are the primary or secondary observer	Primary observer may respond to cues from secondary observer, particularly at low-bird-density locations; matching detections is error prone; recommend use of fixed-radius counts to reduce potentially serious problems associated with differences in distances at which different observers detect birds	Bart & Earnst 2002; Nichols et al. 2000	Alldredge et al. 2006, 2008; Simons et al. 2009
Time-of-detection point counts (multi-observer, removal or time-interval counts)	Recommended for species with constant (and relatively frequent) singing rate. Unsuitable for wide-ranging species and areas with many species and birds	All habitats; particularly useful for dense habitats or difficult terrain	There is no change in the population of birds within the detection radius during the count; there is no double-counting of individuals; constant per minute probabilities of detection; if counts within a limited radius are used, observers accurately assign birds to within or beyond the radius used.	Species that sing in irregular bouts and stay relatively hidden - the apparent population will be significantly smaller than the true population. Long duration of counts may lead to violation of the assumption that there is no double-counting of individuals	Farnsworth et al. 2002	Alldredge et al. 2007a; Simons et al. 2009

Appendix 3-5 – Key assumptions about detection probabilities

Table A3-5-1 A summary of the key assumptions about detection probabilities underlying bird community or population parameters using data collected with unadjusted count methods

State variable	Assumptions	Key references to inform study design
Abundance	The number of birds recorded for a given species is an index that is assumed to have a consistent, positive correlation with actual bird density, i.e. the detection probability for all individuals is similar for different times, places and species for which abundance comparisons are to be made.	Buckland et al. 2008; Nichols et al. 2000
Species occupancy	The probability of detecting a species, given that it was present, is similar at the times and places where comparisons are to be made.	MacKenzie et al. 2002; MacKenzie 2005; MacKenzie & Royle 2005; Nichols et al. 2008; Guillera-Arroita et al. 2010; Efford & Dawson 2012
Species distribution	Species presence can be reliably detected given enough effort.	Bibby et al. 2000
Species richness	All species are detected, or at least are detected with equal probability (but can be biased towards abundant and widespread species, which are likely to show diminished responses).	Boulinier et al. 1998; Nichols et al. 1998, 2008; Zipkin et al. 2010; Dorazio et al. 2010
Species diversity	Individuals of all species are equally detectable and/or that all species are detected.	Yoccoz et al. 2001

Appendix 3-6 – Informing trade-offs in sampling design

Table A3-6-1 Minimum detectable absolute change in occupancy (Δψ) for bird species (classified as very large: $\Delta\ \psi \geq 0.65$, large: $0.45 \leq \Delta\ \psi < 0.65$ or moderate: $0.25 \leq \Delta\ \psi < 0.45$) in relation to varying the number of sampling locations (n_{loc}), detection probabilities (p), classified as high ($p \geq 0.6$), moderate ($0.4 \leq p < 0.6$), low ($0.2 \leq p < 0.4$), and land cover types (non-forest and forest; n_{spp} = total number of bird species observed in each). Species with $p < 0.2$ are excluded, bold highlights species with $p > 0.2$ in both habitats (MacLeod et al. 2012d)

p	Native species Forest (n_{spp} = 23)	Non-forest (n_{spp} = 29)	Introduced species Forest (n_{spp} = 9)	Non-forest (n_{spp} = 22)	Δ Ψ n_{loc} = 40	n_{loc} = 80	n_{loc} = 120	n_{loc} = 240
High	**Bellbird** **Silvereye** **Grey warbler** NZ robin Rifleman Tomtit		**Chaffinch**	**Greenfinch** Magpie **Yellowhammer** Goldfinch House sparrow Skylark	Large	Moderate	Moderate	Moderate
Moderate	**Brown creeper** Fantail Tūī Whitehead	**Bellbird**	**Blackbird** **Dunnock**	**Chaffinch** **Blackbird** **Song thrush** **Redpoll** Starling	Large	Moderate	Moderate	Moderate
Low	Kererū Kingfisher Parakeet species Shining cuckoo Long-tailed cuckoo Yellowhead	**Silvereye** **Grey warbler** **Brown creeper** Paradise shelduck Welcome swallow Harrier Black-backed gull Pied oystercatcher Spur-winged plover	**Greenfinch** **Song thrush** **Redpoll**	**Dunnock**		Very large	Large	Moderate

Table A3-6-2 Minimum detectable relative change (%) in occupancy ($\Delta\psi$) for bird species in relation to varying no. of sampling locations (n_{loc}), detection probabilities (p), classified as high ($p \geq 0.6$), moderate ($0.4 \leq p < 0.6$), low ($0.2 \leq p < 0.4$) and land cover types (non-forest and forest; n_{spp} = total no. of species observed). Species with $p < 0.2$ are excluded, bold highlights species with $p > 0.2$ in both habitats. Mean occupancy estimates for each species are in brackets (MacLeod et al. 2012d)

<table>
<tr><th>p</th><th colspan="2">Native species</th><th colspan="2">Introduced species</th><th colspan="4">Δ Ψ</th></tr>
<tr><th></th><th>Forest (n_{spp} = 23)</th><th>Non-forest (n_{spp} = 29)</th><th>Forest (n_{spp} = 9)</th><th>Non-forest (n_{spp} = 22)</th><th>n_{loc} = 40</th><th>n_{loc} = 80</th><th>n_{loc} = 120</th><th>n_{loc} = 240</th></tr>
<tr><td rowspan="3">High</td><td>**Grey warbler (0.95)**
Tomtit (0.93)</td><td></td><td></td><td>Magpie (1.00)
Yellowhammer (1.00)
Skylark (1.00)
Goldfinch (0.99)</td><td>50%</td><td colspan="3" rowspan="2">25%</td></tr>
<tr><td>**Bellbird (0.86)**
Silvereye (0.75)</td><td></td><td>**Chaffinch (0.78)**</td><td></td><td></td></tr>
<tr><td>Rifleman (0.60)
NZ Robin (0.45)</td><td></td><td></td><td></td><td></td><td colspan="3">50%</td></tr>
<tr><td rowspan="3">Moderate</td><td></td><td></td><td></td><td>**Chaffinch (1.00)**
Blackbird (0.99)
Greenfinch (0.96)
House sparrow (0.93)
Song thrush (0.96)
Redpoll (0.94)
Starling (0.97)</td><td>50%</td><td colspan="3">25%</td></tr>
<tr><td>**Brown creeper (0.57)**
Fantail (0.64)
Tūī (0.58)</td><td></td><td>**Blackbird (0.57)**</td><td></td><td></td><td colspan="3">50%</td></tr>
<tr><td>Whitehead (0.19)</td><td>**Bellbird (0.32)**</td><td>**Dunnock (0.08)**</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Low</td><td></td><td>Spur-winged plover (0.90)
Black-backed gull (0.89)
Harrier (0.97)</td><td></td><td></td><td></td><td></td><td>50%</td><td>25%</td></tr>
<tr><td>Parakeet spp. (0.50)</td><td>**Grey warbler (0.67)**
Welcome swallow (0.63)
Paradise shelduck (0.62)
Pied oystercatcher (0.62)
Silvereye (0.46)</td><td>**Redpoll (0.39)**</td><td>**Dunnock (0.62)**</td><td></td><td></td><td></td><td>50%</td></tr>
<tr><td>Kererū (0.35)
Shining cuckoo (0.21)
Kingfisher (0.14)
Long-tailed cuckoo (0.22)
Yellowhead (0.07)</td><td></td><td>**Greenfinch (0.14)**
Song thrush (0.31)</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table A3-6-3 Minimum detectable change in bird densities (small = 5%; moderate = 10%, large = 20%, very large = 50%) under different sampling scenarios and varying the precision in density estimates (measured using the coefficient of variation), number of sampling locations (n_{loc}), and (c) land cover types (non-forest and forest habitats). Density estimates were only available for six species (highlighted in bold) in both land cover types.

<table>
<tr><th colspan="2">DENSITY ESTIMATE</th><th colspan="2">NATIVE SPECIES</th><th colspan="2">INTRODUCED SPECIES</th><th colspan="6">MINIMUM DETECTABLE CHANGE IN DENSITY</th></tr>
<tr><th rowspan="2">Precision category</th><th rowspan="2">CV Range</th><th rowspan="2">Forest</th><th rowspan="2">Non-forest</th><th rowspan="2">Forest</th><th rowspan="2">Non-forest</th><th colspan="3">One-sample case</th><th colspan="3">Two-sample case</th></tr>
<tr><th>n_{loc} = 40</th><th>n_{loc} = 80</th><th>n_{loc} = 120</th><th>n_{loc} = 40</th><th>n_{loc} = 80</th><th>n_{loc} = 120</th></tr>
<tr><td rowspan="2">High</td><td>5–10%</td><td>**Grey warbler**
Tomtit</td><td></td><td></td><td>Skylark
Yellowhammer
Goldfinch</td><td rowspan="2" colspan="3">Small</td><td>Moderate</td><td colspan="2">Small</td></tr>
<tr><td>11–15%</td><td>**Bellbird**
Silvereye</td><td>Harrier</td><td>**Chaffinch**</td><td>**Chaffinch**
Blackbird
House Sparrow
Magpie
Redpoll
Song thrush</td><td>Large</td><td>Moderate</td><td>Small</td></tr>
<tr><td rowspan="2">Moderate</td><td>16–20%</td><td>Rifleman
Tūī
Brown Creeper
Kākāriki spp.</td><td></td><td>**Blackbird**</td><td>Greenfinch
Starling</td><td>Moderate</td><td colspan="2">Small</td><td>Large</td><td colspan="2">Moderate</td></tr>
<tr><td>21–25%</td><td>**Fantail**
NZ Robin</td><td>**Bellbird**
Grey warbler
Silvereye
Black-backed gull
Spur-winged plover
Pied oystercatcher</td><td></td><td></td><td rowspan="2">Large</td><td rowspan="2" colspan="2">Moderate</td><td colspan="2">Large</td><td rowspan="2">Moderate</td></tr>
<tr><td rowspan="2">Low</td><td>26–30%</td><td></td><td>Welcome swallow
Paradise shelduck</td><td></td><td>Dunnock</td><td rowspan="2">Very large</td><td>Large</td></tr>
<tr><td>31–40%</td><td></td><td>**Fantail**</td><td></td><td></td><td colspan="2">Large</td><td>Moderate</td><td colspan="2">Large</td></tr>
<tr><td>Very low</td><td>50–60%</td><td></td><td></td><td></td><td>Feral pigeon</td><td>Very large</td><td colspan="2">Large</td><td colspan="3">Very large</td></tr>
</table>