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Assessment of Data Sources for Monitoring Birds In Cape to City

Assessment of Data Sources for Monitoring Birds in Cape to City

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What impressed you most about this project?

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Summary

Project and Client

- Assessment of Data Sources for Monitoring Birds In Cape to City, Hawke's Bay Regional Council

Objectives

- Describe the issues associated with aggregating unstructured citizen science data and present recommendations as to how citizen science can be designed to provide reliable information on species distribution over time.
- Describe the various data sources that are currently and potentially available for native birds within the Cape to City footprint, and discusses their value with respect to informing on the status and changes in bird distribution.

Aggregating Unstructured Citizen Science Data

- In recent years there has been a vast increase in the amount of observations of species gathered by members of the public, commonly termed 'citizen science data'. This type of data is generally unstructured in that individuals will chose which locations to visit, which methods to use and which species to record.
- Each individual record is as reliable as any gathered by professional technicians as part of a structured survey. Issues arise however when we try and aggregate the individual observations into a metric for reporting on changes in species distribution and/or abundance.
- Generally however, the unstructured nature of the observation process means that the data are more prone to biases due to (i) bias towards some species, (ii) incidental records with no recording of effort, (iii) differing survey methods among observers, (iv) no recording of species absence, and (v) pseudo-replication.
- There are some potential solutions for reducing the bias in existing data for the purpose of constructing a reporting metric, including (i) binning the individual records into spatial units, (ii) explicitly accounting for imperfect detection using occupancy modelling, (iii) sub-setting the data to remove observations where only some species were searched for, or where survey effort is not record, and (iv) reducing the region of inference to only include areas which have been consistently monitored.

Data Sources for Cape to City Bird Monitoring

- There are a number of current and potential data sources that could be used to monitor native birds in Cape to City
  - i) Structured Monitoring of Birds
  - ii) Tier 1 Monitoring

iii) Surveys of land-owners

iv) New Zealand Garden Bird Survey

v) Citizen science databases, such as NatureWatchNZ and eBird

- These data sources vary greatly in terms of their level of structure with respect to the observation process, the cost, and the extent and value of information they contain.

Conclusions & Recommendations

- In recent years there has been a vast increase in the amount of species observations gathered by members of the public. These citizen science records are arguably as valid as those collected by professional technicians. Issues arise however when we attempt to aggregate these ‘unstructured’ data into a metric for reporting purposes. Because they are often gathered opportunistically, there is little or no information on the observation process.
- There are some analyses we can apply to unstructured data in order to mitigate the effects of the observation process. However, if we wish to use citizen science data for reporting, we would ideally design a monitoring program where methods are standardised and the collection process is coordinated in order to achieve good spatial coverage and result in a metric that is robust and repeatable. This would require significant resourcing.

1 Introduction

Cape to City is a predator control and ecological restoration project covering 26,000 ha in the Hawkes Bay region, encompassing the Cape Sanctuary wildlife restoration project on the Cape Kidnappers peninsula. The objective of Cape to City is "*to see native species co-exist with human habitation, food production and recreation at large scales on our agricultural primary productivity landscape*"[1]. One way that this objective is being achieved is by controlling introduced predators such as stoats, ferrets and feral cats. It is expected that this predator control will protect remnant populations of native bird species in the Cape to City footprint, and will aid in the dispersal and re-colonisation of rare native birds from the fenced Cape Sanctuary into the adjacent landscape.[2] It is anticipated that the predator control will have a positive impact of native birds in Cape to City, however in order to assess the effectiveness of the control program requires some level of ecological monitoring.

1.1 Monitoring: what do we want to measure and what do we actually observe?

Ecological monitoring is carried out in order to gain insight about an **ecological process**, e.g. "*The distribution of bellbird/korimako in the Cape to City area and how it changes over time*". In general, the ecological process will never be fully observable, i.e. we will never know where every bird is at every point in time.

The data we collect is a combination of the ecological process and the **observation process** (e.g. *where* we look, *how* hard we looked, and *what* we looked for). The extent to which the observation process clouds our view of the ecological process depends on a number of factors which are discussed in section 2. Problems are compounded when the observation process changes over time potentially inducing a change in the observed data which we incorrectly attribute to a change in the ecological process.

The aim of monitoring is to obtain a clear picture of the ecological process and therefore make robust inference about the species being monitored. In order to do this, we must eliminate, or at least account for, the effects introduced by the observational process.

1.2 Structured vs Unstructured Monitoring

Monitoring can generally be thought of either *structured* or *unstructured*. In *structured* monitoring, surveys are performed at randomly selected sites using a consistent and repeatable methodology, typically by professional research technicians. A potential limitation of structured monitoring is that it is expensive and time consuming and as a result only a limited number of locations can be monitored.

Over the past few years there has been a vast increase in the amount of 'citizen science data': these are observations of species gathered by members of the public (as opposed to professional scientists/technicians), usually housed in online data repositories (see 4.5).

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[1] http://capetocity.co.nz/about/

[2] http://www.landcareresearch.co.nz/publications/newsletters/kararehe-kino/kararehe-kino-issue-25/wide-scale-predator-control

Monitoring by citizen scientists is generally *unstructured*: individuals will visit locations of interest to them and will use their own survey methods. It is undeniable that these data repositories contain a lot of rich information; however what is less clear is whether this citizen science data can be used to provide robust inference about species distribution and changes. It is worth noting that citizen science monitoring is not always unstructured. For example the recent State of Australia's Birds report[3] used citizen scientists to collect data from which composite indices were constructed (Cunningham and Olsen 2009). Similarly, the Breeding Bird Survey[4] is a national volunteer project that aims to track changes in populations of widespread birds in the UK. In these two examples, there is a high level of coordination and consistency of methods among the citizen scientists. A local example is the New Zealand Garden Bird Survey (see section 4.4): this is considered a *semi-structured* monitoring program in that the participants use a consistent method for making observations, however they can do the survey at any location they chose.

2 Objectives

This report describes:

- Issues associated with aggregating unstructured data, typical of that entered into citizen science repositories, and how citizen science can be designed to obtain data on species distribution over time (section 3).

- The value of various data sources that are available (or potentially available) for native birds within the Cape to City footprint, and discusses their potential to inform on the status and changes in their distribution given the quality of the biodiversity information and the cost of collection (section 4).

3 Aggregating Unstructured Data

Unstructured data, such as the individual observation records in citizen science databases, are arguably as reliable as any that would result from monitoring by professional research technicians, especially considering the skills and vast experience of many of the citizen science observers. We can generally assume that if a record in a citizen science database includes an observation of a specific species, then that species was indeed detected. There are likely to be some false presences due to misidentification, however these are expected to be similar to those from professional technicians. The issue with unstructured data is when we attempt to aggregate it into a metric for monitoring purposes.

[3] http://birdlife.org.au/education-publications/publications/state-of-australias-birds

[4] https://www.bto.org/volunteer-surveys/bbs

In this section, we present some issues associated with aggregating unstructured data and how it can affect the inference that is being made. To illustrate the issues, we use data from eBird (section 4.5) in the Greater Wellington region, specifically records of tūī over the period 2011 to 2014. More detailed discussion of these points is available in Gormley & MacLeod (in prep).

3.1 What the data can and cannot tell us

Citizen science databases such as eBird generally consist of records of species detections, which can be mapped to depict where species were detected (blue/closed dots; Figure 1), and therefore identify areas they inhabit or utilise. However, the data do not necessarily tell us which areas tūī do not inhabit or utilise. We therefore can have confidence in what the data tell us about species presence but little confidence about species absence.

For example, despite there being a large number of eBird records that do not contain observations of tūī (white/open dots; Figure 1), it is unclear what these mean in terms of actual presence/absence. Were tūī observed but just not recorded? Were they present, but not observed? Were tūī present, but unable to be identified? Were they truly absent? It is apparent that a non-detection does not necessarily equal an absence. Furthermore, there are large areas where there were no observation records at all: what inference can we make about tūī presence/absence in those regions?

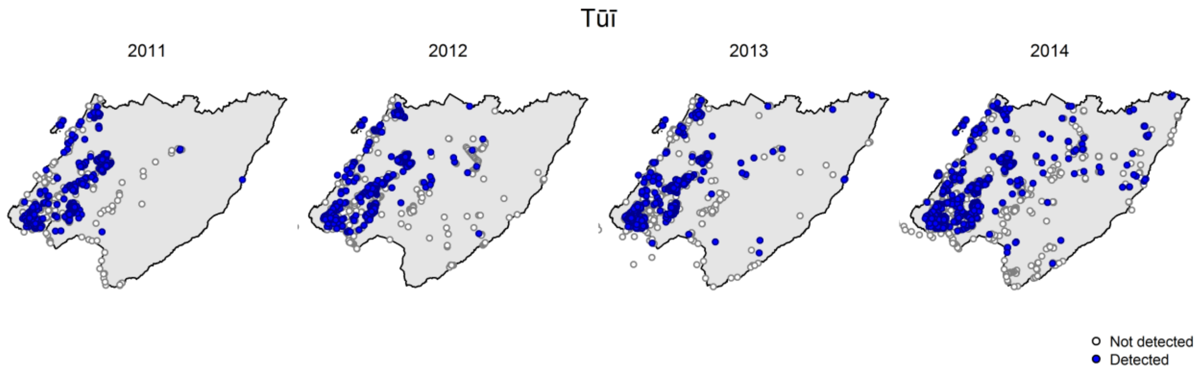

Figure 1: Map of all eBird observations of tūī between 2011 and 2014 in the Greater Wellington region. Blue and white dots depict observation events which included and did not include an observation of the species respectively.

3.2 Issues with aggregating data

For monitoring we need to construct a metric from the data that can be tracked over time. The implication is that an increase in tūī will result in an increase in the metric, and vice versa for a decrease. Similarly, comparing the metric calculated for one species (e.g. tūī) against another (e.g. blackbird) will permit reliable comparisons. One basic metric is to take the number of records with detection of our species of interest (e.g. tūī) and divide that by the total number of records. Unfortunately a consistent relationship between tūī numbers and the metric is unlikely to hold due to the factors presented below.

3.2.1 Species characteristics can affect reporting rates

Species can be recorded in a manner that has little to do with their distribution/abundance. An observation of an uncommon species is more novel and therefore may have a greater likelihood of being recorded. This reporting bias can result in rarer species being recorded more often than common species. A further paradox that can eventuate is that when a rare species becomes more common over time, it may be reported relatively less often leading to data that suggests it is stable or even declining.

This reporting bias may not be based solely on distribution or abundance, but also on species characteristics. For example, native species such as tūī are considered more 'interesting' than introduced species such as blackbird, and may therefore be reported more often, irrespective of their underlying distribution/abundance. Indeed some observers limit themselves to a subset of species and only enter records of those.

In *structured monitoring*, all species that are detected are recorded (i.e. full species lists are recorded). The eBird organisation encourages its submitters to do this to some degree by urging them to enter a 'full list', that is, to record all species that the observer detected and were able to identify: any species not recorded could therefore be assumed to have been undetected. However it should be noted that a full list will omit species that may have been observed but were unable to be correctly identified. Ideally, the detection and non-detection of all species of interest should be explicitly recorded, removing any doubt about which species were looked for during a survey event.

3.2.2 Spatial Bias and Representativeness

Unstructured monitoring data often suffers from issues with spatial bias. Observations are generally highly clustered with most records close to major population centres. For example, the eBird records for Greater Wellington are clustered predominantly around Wellington City (Figure 1). This type of spatial bias will mean that any species that is more commonly distributed in areas away from human populations (e.g. in public conservation land, regional parks, private rural land) will be recorded less often and will therefore be assumed to be relatively rare compared to a species that is more common around urban/suburban areas and therefore observed and recorded more often.

Further problems arise when the sampling distribution changes over time (e.g. increased sampling in the less populated areas), which may result in an increase in observations of a species, even if its distribution remains constant.

A related issue is that of representativeness: any inference from the data only applies to the region that is sampled. If there are large areas of a region that have no observation events, then any inference about the species cannot apply to those un-sampled areas. Similarly, if the region that is sampled changes over time, then this can suggest changes in distribution that have nothing to do with changes in the species. For example, the eBird data may appear to suggest that tūī have increased their range eastwards across the Greater Wellington region from 2011 to 2014 (Figure 1), however in reality, whilst there were very few observations of tūī in the east in 2011, there were also very few observation events at all in that area.

Structured monitoring attempts to mitigate these issues by initially considering all possible survey locations, and then selecting a subset of those locations which is expected to be representative of all locations. Sites can be chosen by a number of methods: simple random sample, stratified random sample, systematic sample (i.e. a grid), or a spatially balanced sampling design. Ideally, sampled locations are distributed across the entire region, and across all habitat types that we want to make inference about. The summary of data from the measured locations can then be used to make inference about the entire region.

3.2.3 Pseudo-replication

Pseudo-replication occurs when related samples are treated as independent ones. This is illustrated with a simple example: consider the case where we have 10 observers all of whom visit a different location to monitor tūī. If tūī are present at 1 out of 10 of those locations, and are observed without error, then the value for our metric (proportion of events where tūī are observed) is 0.1. If however five of the observers unwittingly visit the same location where tūī are present then we would have 5 observation of tūī out of 10 observation events resulting in a metric of 0.5. However multiple observers visiting the same site does not result in independent events and therefore they should not be treated as such – those five observers have essentially just repeated the same observation event 5 times. This is fundamentally what happens when we aggregate spatially clustered observation events. Many observations are recorded in close proximity (temporally and spatially) are essentially repeat measures of the same location. Therefore, even though the information for each individual observation event is correct and valid, the issue arises when we combine the data.

Structured monitoring attempts to avoid this problem by pre-allocating the sampling locations, making sure they are some minimum distance apart, and visiting each location the same number of times and sampling each with the same amount of effort whenever possible.

3.2.4 Variable Search Effort

The individual observation events will also have varying levels of observer effort associated with them. Generally speaking, the longer an observation event lasts, the greater the chance of detecting those species that utilise/occupy the area. The consequence of this can be significant especially if different survey types are performed in different regions or in different years. For example if the surveys in a particular year are generally longer than those in the following year, then the effect might be that the species is detected more often in the first year and less in the second year leading to the incorrect conclusion that the species has declined.

In *structured monitoring*, surveys are standardised in term of their methodology, survey length and distance/area covered. At the very least, this means that any bias in the data is consistent both between different areas and over time.

3.3 Potential solutions for current data

There are a number of methods that can be used to partially mitigate the issues associated with aggregating unstructured data into a metric for reporting.

3.3.1 'Binning' the Data

One way of reducing the effects of pseudo-replication (multiple non-independent measures of the same thing) is to collate the data into geographic bins. For example, Figure 2a shows detection/non-detection of tūī in 2012 (red and white dots, respectively), with those records then collated into grid cells of various sizes, where each cell is coloured according to whether it was *detected* (there was at least one tūī detection; green squares), *not detected* (no tūī detections; blue squares), or it was *not surveyed* (no observation events; grey squares). A simple estimate of occupancy/utilisation (apparent occupancy) can be obtained by dividing the number of grid-cells with at least one detection by the total number of cells that were surveyed.

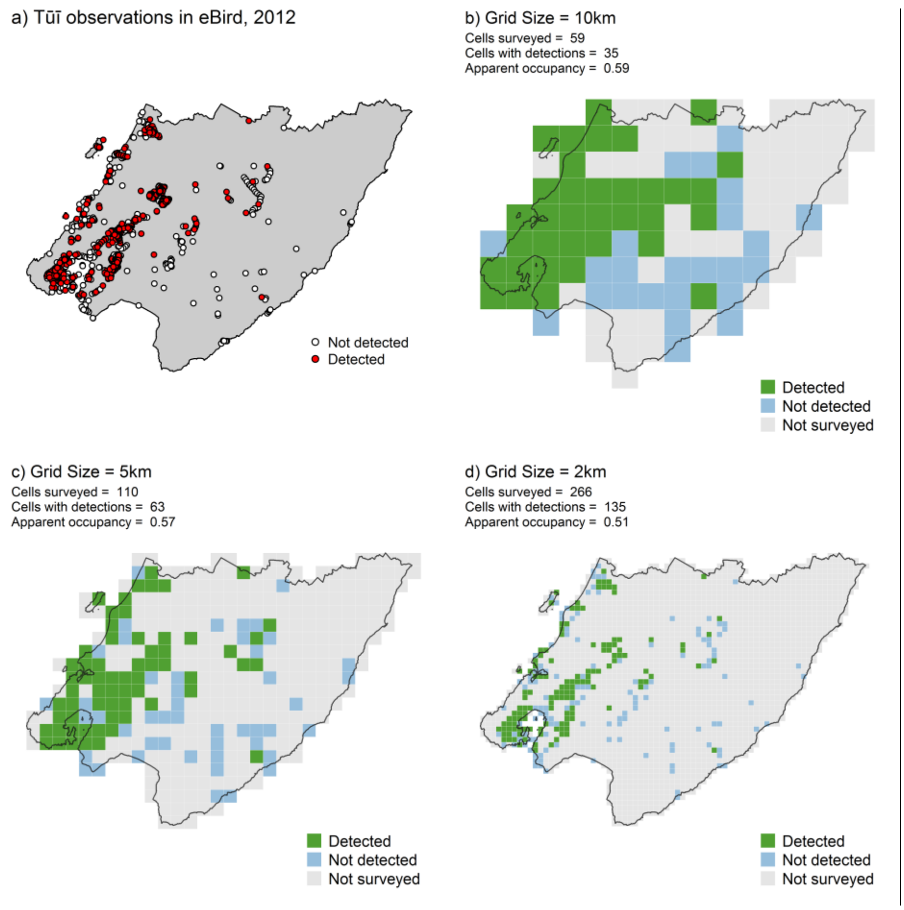

Figure 2: a) Raw data of detection and non-detections of tūī in 2011 from eBird (red and white dots), and aggregated into (b) 10 × 10 km, (c) 5 × 5 km and (d) 2 × 2 km grid cells. Each cell is classified as detected, not detected and not surveyed (left), and estimates of apparent occupancy at various grid cell sizes (right).

Binning the data reduces the effect of pseudo-replication by treating observations within a grid cell as repeat measures of that grid cell rather than as truly independent observations. The cost of doing this is that the sample size is greatly reduced: in 2012 there were 1750 observation events in eBird in the Greater Wellington region, whereas with a 10 × 10 km grid cell, the sample size consists of just the 59 grid cells. This reduction in sample size is not as much as a problem as it may seem, as the original sample size of n = 1750 was greatly over-inflated due to pseudo-replication.

The choice of grid resolution is not clear cut. The grid cell size should be chosen that best matches the extent of the surveyed area (Higa et al 2014). For example, if a survey consisted of measures over an area of 500 × 500 m area, then that defines the grid cell size. For data in eBird however, this is not clear as there is no consistent survey length used: some observations are from counts over varying distances, whereas others are point locations. Furthermore, sites should be large enough to have a reasonable chance of the species being there, but small enough that any measure of occupancy is meaningful and the site can be surveyed adequately with a reasonable level of effort (MacKenzie et al 2002).

An important point to note is that any estimate of occupancy is specific to the size of the site or spatial unit: the estimate of occupancy decreases as the grid cell size decreases (Figure 2). Furthermore, the larger the grid square, the greater the apparent coverage of the survey. However, just because a grid cell contains an observation event does not mean the entire grid cell was surveyed.

3.3.2 Accounting for imperfect detection

It is apparent from Figure 2 that for all grid cells where tūī were detected (green squares), there were a number of observation events within the grid cell where it was not detected (white dots). This non-detection in grid squares where tūī are known to occur means that in surveyed grid squares where there were no detections (blue squares), the species may actually utilise that square, but it was just not detected on any of the observation events (i.e. *false negatives*). The consequence of these missed *presences* is that the estimate of apparent occupancy for any grid cell size is likely to be biased low.

Regardless of the reason for the missed detections (i.e. species misidentification, not actually looking for the species in question, did not see or hear it when present, species was not in the immediate area being surveyed etc), if we can explicitly account for the detection probability of a species, we can obtain a less biased estimate of occupancy.

One potential approach is to analyse the data using an occupancy modelling framework (MacKenzie et al. 2002). Occupancy models explicitly separate out the ecological and the observation processes. In this framework, the 'repeat' observation events within a grid cell are not used as additional samples for the metric but rather used to obtain information about detection probability. For example if a location was visited by two different observers and tūī detected by only one of them, then the approximate detection probability of tūī is

0.5. For another location where tūī were not detected by either observer, there is still a 25% chance that tūī are present but were just not detected.

3.3.3 Sub-setting the Data

If we are constructing a metric for reporting, then it is recommended to only use data where the observers reported a full list of species (i.e. record the presence of all species) as opposed to a partial list (i.e. only record those species that you are interested in). Reporting full lists is encouraged by eBird, and over the last six years, the number of full list observations has increased dramatically. Only using data from full lists to construct the metric will result in observation records associated with partial lists being excluded from the analysis. This may result in a species being designated as 'not-detected' in a grid cell if they were detected on a partial list only, resulting in a lower estimate of apparent occupancy. The 'loss' of data however is outweighed by an improvement in data quality and consistency, and overall reduction in bias.

It may also be preferable to only include observation events where there has been some recording of effort, i.e. the duration of the survey and/or the distance covered. This would eliminate a large number of incidental observations, however, in eBird at least, many of these are associated with partial lists, and would potentially be excluded anyway for the purpose of constructing a reporting metric.

3.3.4 Reducing the Region of Inference

Observers will generally make their observation close to where they live, and in places that are easily accessible. Any inference we make from the data will not (and cannot) apply to any area that has not been sampled. For example, an estimate of the complete regional distribution of tūī is not possible from eBird data, as there are large areas in the Greater Wellington region that have not been sampled.

It may however be possible to make inference about smaller areas within the region that do have adequate survey coverage, for example, around Wellington City (Figure 3). For the past four years, there are $n = 94$ grid cells of 1×1 km that contain observations in at least two of the last four years. Using this subset of data will result in a more reliable estimate of trend, however that trend will only apply to the smaller region.

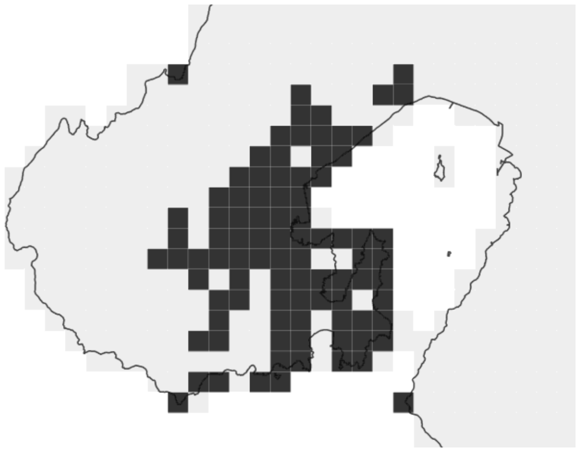

Figure 3: The region around Wellington City showing 1 × 1 km grid cells with records in eBird in at least two years between 2011 – 2014.

A related issue that is common to all monitoring (including structured monitoring) is access to private land. Negotiating access may be impossible, or at the least very time consuming. Monitoring that does not include locations from a specific land-type (landuse/class/habitat/ownership) cannot be used to make inference about those land types. For example, DOC's Tier 1 monitoring only occurs on public conservation land and therefore any inference can only be made about public conservation land and cannot be reliably extrapolated to private land.

3.4 Recommendations for Future Data

The points raised in section 3.3 will reduce the effect of the sampling bias that likely exists in unstructured citizen science data for the purpose of monitoring. However, for the future, it is desirable to add some structure to the monitoring. These additional recommendations apply predominantly to the data collection process.

3.4.1 Coordination of effort

A major advantage of citizen science is the large number of observers who collect data freely on their own time. To make the most of this resource, there would be a level of coordination so that the sampling distribution is structured and unbiased, and that spatial coverage is adequate. This might involve encouraging citizen science observers to collect the data in specific areas using the same sampling protocol. Potential ways of coordinating effort could be to incentivise the process by inducing competition among observers. For example, maps of effort could be generated and made live so that observers can immediately 'see' the grid cells that have had little or no observation effort. Competition among observers could be generated by observers acquiring points or rewards for surveying these areas.

3.4.2 Standardised Monitoring

In addition to coordination of field effort, standardisation of monitoring methods is important. Data collected by standard methods can more easily be combined across different observers. Standard sampling methods are not critical if we use occupancy as a metric and account for detection probability using occupancy modelling. However, if we wish to measure abundance then the manner in which count data are recorded must be standardised (e.g. five-minute bird counts).

The method used will vary depending on the intent of the monitoring. For example, monitoring of multiple species will require methods that are best suited to a range of species, but may not be optimal for every species, whereas monitoring a single species will use the method that maximises detection of that species, at the potential exclusion of other species that may be of interest. For example, monitoring using five-minute bird counts will tend to detect the majority of species, however it is highly unlikely to detect nocturnal species such as kiwi. Kiwi, for example, are monitored using call counts, with surveys typically carried out during the first two hours darkness (McLennan 1992).

4 Data Sources for Cape to City Monitoring

The previous section introduced some of the issues and potential solutions with using unstructured citizen science data for monitoring, as well as giving recommendations for introducing structure to citizen science data. In this section we discuss the current and potential data sources that could be used to monitor birds in Cape to City. We outline the appropriateness of each and indicate any potential limitations with respect to bird monitoring.

4.1 Structured Bird Monitoring

A program led by John McLennan (EnviroServices) has been initiated as part of the Cape to City project and will run from 2015 to 2020. The programme has three aims:

1. to measure changes in the abundance of waterfowl and game birds in the 'Cape to City' footprint area and surrounding non-treatment sites
2. to measure and document the spread of various native species from Cape Sanctuary into the 'Cape to City' footprint area
3. to monitor translocated robins and tomtits into Mohi Bush and whio or kiwi into the Maraetotara River using founders sourced from various parts of Hawkes Bay.

In terms of the second objective, the species of interest are robin, tomtit, whitehead, red-crowned kakariki, pāteke, and kākā. Monitoring is conducted in exotic and native forest patches within Cape Sanctuary (four transects), in the wider Cape to City footprint (nine transects), and at non-treatment blocks outside of Cape to City (six transects). The methods vary among species: robins, tomtits and whiteheads will be counted when seen or heard responding to taped calls along transects in native and exotic forests at varying distances from Cape Sanctuary. Kakariki and kākā will be counted when heard or seen during the play-back survey.

The methods are standardised and repeatable with effort accounted for explicitly due to the use of standard transect length and monitoring period. There will be four counts per year which will enable seasonal counts to be obtained. The first year of monitoring has been completed and the results will soon be available in a separate report from EnviroServices.

The quality of the information from this monitoring is likely to be very high. The study has been designed specifically for the purpose of detecting changes in abundance of a subset of species and uses consistent and repeatable survey methods. The cost of collection is also likely to be high (relative to the other data sources mentioned in this section), however that expense is likely to be cost-effective considering the data quality and therefore the increased ability to be able to detect a change in abundance.

4.2 'Tier 1' Monitoring

Within the last five years the Department of Conservation have been collecting a range of biodiversity information on a wide range of taxa at locations that occur on the intersection of a national 8 × 8 km grid on public conservation land (i.e. Tier 1).[5] For birds, monitoring consists of five-minute bird counts followed by five-minute distance sampling counts at five stations per sampling location. Some regional councils are using the same method on private and council administered land, such as regional parks: for example, Greater Wellington Regional Council has completed bird monitoring at 44 locations on private land and regional parks to supplement the 10 locations measured by DOC (Figure 4). The benefit of a consistent approach is that the data can be combined with DOC's data so that a region-wide estimate can be constructed.

[5] http://www.doc.govt.nz/our-work/monitoring-and-reporting-system/

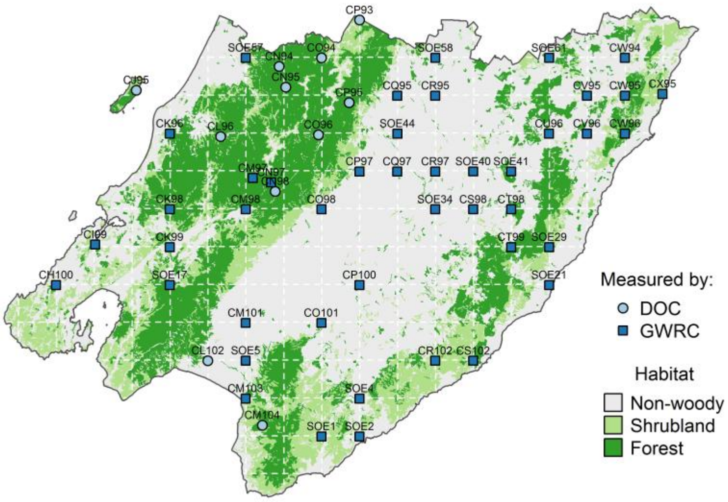

Figure 4: Map of locations in the Greater Wellington region where bird monitoring has been carried out. Light blue circles indicate sampling locations on public conservation land that were measured by DOC, whereas dark blue squares indicate sampling locations on private land or regional parks that were sampled by GWRC.

The Cape to City footprint however contains no Tier 1 locations on public conservation land, and therefore does not have any monitoring carried out by DOC. There are four points from the 8 km network, with four more within 4 km of the edge of the Cape to City footprint (Figure 5). However, this small number of sampling locations is obviously not enough to provide reliable information on birds in Cape to City. Furthermore, the small number of locations means they are unlikely to be representative of habitat/land-use types across the region of interest.

DOC is currently refining the sampling framework using a spatially balanced, probabilistic sampling method called balanced acceptance sampling (Robertson et al. 2013) in order to create a nation-wide 'Master Sample' that can be used to augment the 8 × 8 km grid. By selecting sampling locations from the master sample, locations will be spatially balanced and independent, thereby eliminating issues of pseudo-replication and representativeness. Furthermore, by selecting sampling locations from the master sample, and by using consistent monitoring methods, the results can be more easily combined or compared with monitoring from other studies, such as the proposed Pan Regional Predator Control project which is planned to be carried out across four region council jurisdictions.

The cost of data collection is also relatively high for Tier 1 monitoring as it relies on field visits from professional technicians. As with the specific monitoring project mentioned above, the quality of the data for the purposes of monitoring is also likely to be high. Furthermore, by selecting locations from a master sample, the data will be comparable and compatible with data from other areas obtained using the same methodology.

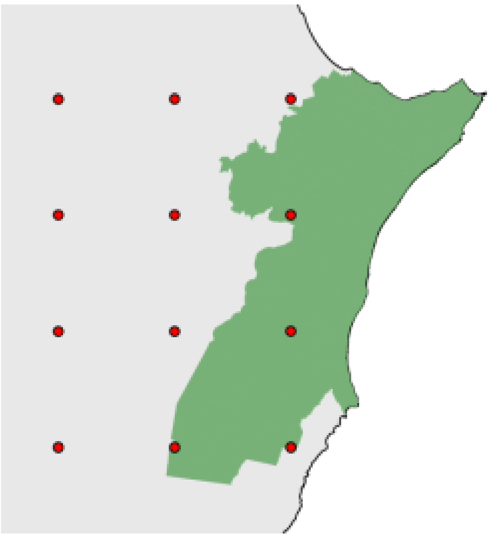

Figure 5: The location of potential sampling locations points on the 8 × 8 km grid (red circles) inside and outside the Cape to City footprint (shaded green).

4.3 Surveys of Land-owners

The Cape to City project Communication Survey was administered by Landcare Research in 2015 with the aim to measure changes in the awareness, knowledge, and behaviour of the general public resulting from the Cape to City project. Respondents were predominantly recruited through primary schools in order to obtain access to a range of people living both inside (n = 544) and outside (n = 47) the Cape to City footprint. Survey topics were varied and included biodiversity, habitat restoration, involvement in environmental activities, motivation for becoming involved in environmental activities, reasons for not becoming involved in environmental activities, and sources of information and familiarity with environmental initiatives.

Within the biodiversity section, respondents were asked what native bird species they had observed in the previous year. Results from respondents inside the Cape to City footprint were compared with those outside. For example, respondents inside the Cape to City footprint were more likely to have reported seeing native species such as silvereye/tauhou, morepork/ruru, and bellbird/korimako compared to respondents living outside. It is however unclear whether these differences are a true reflection of differences in distribution and abundance of these species, or whether they simply reflect differences in the observation process. For example, more of the respondents inside the Cape to City footprint reported having participated in the Garden Bird Survey than those outside. This greater likelihood of observing native birds within the Cape to City footprint could therefore simply be a result of residents inside the footprint being more likely to look for native birds (i.e. by taking part in the Garden Bird Survey).

The cost of obtaining the data is relatively low compared to the structured monitoring discussed so far. The reliability of the data, and therefore its value for the purpose of monitoring is questionable due to the issue of there being little information on the sampling process. This could potentially be alleviated by adding some questions in future surveys that ask about how much time was actually spent looking for native birds.

4.4 New Zealand Garden Bird Survey (NZGBS)

The New Zealand Garden Bird Survey[6] is a citizen science survey that consists of data from annual counts from a 10 day period in winter each year. This initiative has a semi-structured survey design, where volunteers select the sampling locations within rural and urban areas, but use standardised bird count protocols. Most records are from private household gardens, although a proportion of surveys are carried out in urban or regional parks, or schools. Participants record the maximum number of individuals seen of each species at any one time over a single one hour period. The NZGBS began in 2007 and is now in its tenth year. These time series data and consistency of methods allows for reliable estimates of trends to be calculated (Spurr 2012). More recent analytical methods have been applied that allow for trends to be extracted at a variety of spatial scales (e.g. regional, statistical area units) whilst explicitly accounting for spatial variation and increasing the sensitivity of these indicators for detecting trends in garden birds (MacLeod et al. 2015).

It is possible that further analytical advances may permit species-specific trends for custom-defined areas, such as the Cape to City footprint. This would however depend on the amount of data that is available from that area. Currently the number of respondents to the NZGBS in all of Hawke's Bay is approximately only 150 per year, and it is not yet clear as to how many of those are within the Cape to City foot print.

The cost of collecting these data is relatively low as it relies on volunteers making and entering their observations. However, the hidden costs (and associated skills required) should not be overlooked; these include the costs of providing supporting materials and engaging and coordinating the volunteers to take part as well as data storage, processing, analysis and reporting. The ability to reliably detect a change from the NZGBS data is increasing due to analytical advances. Developing protocols that capitalise on these statistical advances can be costly in the short-term, but once those standardised protocols are in place, they should not be expensive to maintain.

4.5 Citizen Science Databases

There are two main repositories of citizen science data in New Zealand that may be appropriate for providing information on birds in C2C.

eBird

Birds NZ (formerly the Ornithological Society of New Zealand) have partnered with the Cornell Laboratory of Ornithology and the National Audubon Society to provide an electronic database for bird observations, eBird. It is an online checklist program that

[6] http://www.landcareresearch.co.nz/science/plants-animals-fungi/animals/birds/garden-bird-surveys

enables a wide range of users to submit bird observations into a secure database. Collectively, it contains millions of observations globally. The data can be accessed on request, with the data download available as a '.txt' document containing a line for each observation, including information on the species name, date and time, geographical coordinates, observer name, type of count, effort.

eBird contains information ranging from incidental sightings to records from surveys that contain information on survey effort (stationary counts and travelling counts). Records in eBird are generally of two types: (1) partial counts are where the observer enters a record pertaining to a single species of interest; (2) full counts are where the observer enters a record that consist of all species observed or identified during the survey period.

Despite the potential, the amount of eBird data within the Cape to City footprint is currently very small, and spatial coverage is therefore very poor (Figure 6). In its current state, eBird is unlikely to be able to provide useful information for the purpose of monitoring changes in distribution and/or abundance of native birds.

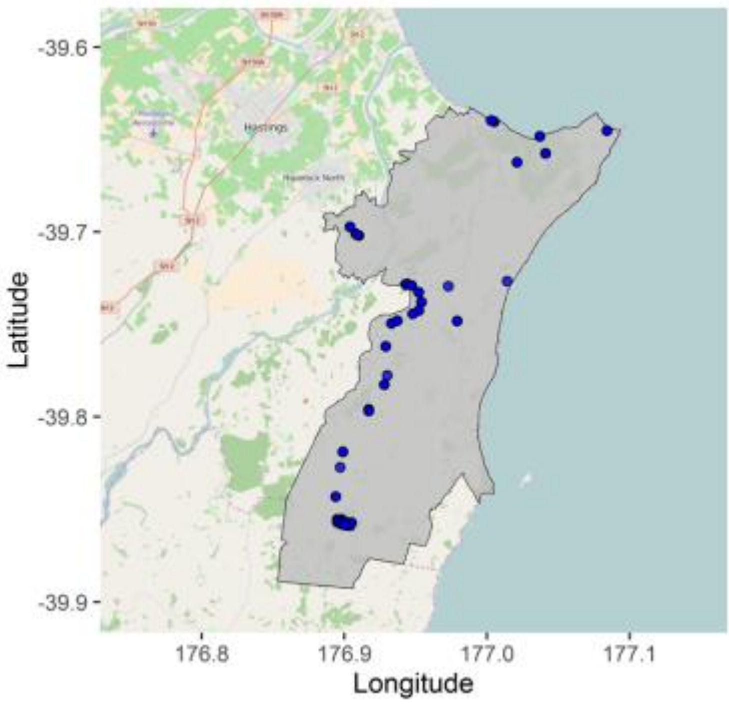

Figure 6: Location of eBird observations (circles) within the Cape to City footprint (shaded) for the period 2010 to 2014.

NatureWatchNZ

NatureWatchNZ[7] is a citizen science repository that is not limited to birds, and includes observations of both flora and fauna. Similar to eBird, it allows for observations to be recorded and uploaded. A feature of NatureWatchNZ is that observations are able to be

[7] http://naturewatch.org.nz/

verified by other users in terms of species identification, generally from uploaded photographs. NatureWatchNZ also allows for 'projects' to be set up and observations linked to those projects. For example, it is the current repository of the New Zealand Garden Bird Survey data, and also contains a project for Cape to City. Currently the data within the Cape to City project consist of 519 observations of 283 species of flora and fauna, the majority of these (n = 507) from a single observer. Only 16 of these observations are of birds. There are however more observations in NatureWatchNZ that occur within the Cape to City footprint, but are not specifically linked to the Cape to City 'project'. The current numbers however are not enough to provide information on changes in species distribution and/or abundance.

The cost of obtaining data from these citizen science databases (NatureWatchNZ and eBird) is essentially nil. However, the value of the data for monitoring purposes is currently very low. Issues with the observation process (e.g. pseudo-replication and reporting bias) mean that a monitoring metric is unlikely to reliably reflect the underlying distribution and abundance of birds. Steps can be made to mitigate some of these issues by processing the data in different ways (see 3.3), however these steps involve analytical costs, and issues of spatial representativeness will likely remain.

5 Discussion

Assessing the efficacy of any pest control program requires monitoring to be carried out. Any monitoring data are a combination of an ecological process (what we are trying to measure) and an observation process (what we see when we try and measure it).

Structured monitoring has the advantage of being standardised and repeatable and can therefore provide relatively unbiased information on species distribution over time. The observation process can be explicitly accounted for so that we can obtain an unbiased view of the ecological process. A weakness of structured monitoring is that it is comparatively costly, and as a result, only a small number of locations may be able to be sampled. Given limited budgets for many monitoring programs, it may be that the number of sampling locations is too small to reliably detect a change in a population.

Citizen science data have the advantage of being relatively cheap (or free) to obtain, and can result in vast quantities of data. Generally however, the unstructured nature of the observation process means that the data are more prone to biases due to:

- Bias towards rare/cryptic/interesting/native species
- Incidental records with no recording of effort
- Differing methods among observers
- No recording of species absence
- Pseudo-replication

If the observation process is unknown or cannot be accounted for, then an aggregated metric is subject to bias and reliable inference about the ecological process may not be possible.

Ideally we would combine the strengths of structured monitoring and citizen science so that we have a monitoring program that is robust and consistent. Harnessing the power of large numbers of volunteers can achieve a much greater level of spatial (and temporal) coverage. This type of coordinated citizen science program would provide potential savings in field costs. However it would also require a significant amount of coordination and therefore resourcing. Furthermore, there are costs associated with data analysis and model development.

These issues of appropriate resourcing and coordination of citizen science echo concerns raised by local community groups and hapū participants (Fitzgerald 2015). In June 2015 four focus groups were held in Hawke's Bay to gauge local interests and views on the proposed monitoring for the Cape to City project. Those groups felt the following specific points needed addressing for the Cape to City project to be successful:

- Finding out where the local community's interest lie and aligning biodiversity monitoring initiatives accordingly

- Tailoring communication to reach different audiences, meet their needs and build collaborations
- Providing incentives and recognition for volunteers, including access to information, good new stories (i.e. highlighting the positive outcomes of their efforts) and some expenses
- Securing commitment and participation from landowners in the project area, in particular for gaining access to private land for community groups to implement biodiversity monitoring there and meeting health and safety obligations
- Providing appropriate education and training opportunities for interested members of the community

6 Conclusions and Recommendations

In recent years there has been a vast increase in the amount of species observations gathered by members of the public. These citizen science records are arguably as valid as those collected by professional technicians. Issues arise however when we attempt to aggregate these ‘unstructured’ data into a metric for reporting purposes. Because they are often gathered opportunistically, there is little or no information on the observation process.

There are some analyses we can apply to unstructured data in order to mitigate the effects of the observation process. However, if we wish to use citizen science data for reporting, we would ideally design a monitoring program where methods are standardised and the collection process is coordinated in order to achieve good spatial coverage and result in a metric that is robust and repeatable. This would require significant resourcing.

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