Birds: complete counts—plot sampling (complete counts of a portion of a study area)

Version 1.0

This specification was prepared by Terry Greene in 2012.

Contents

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Synopsis

Plot sampling involves counting individuals of the target species within discrete areas of known size. The plots are chosen according to some sort of probability-based sampling design (random, systematic, etc.) and are always smaller than the overall survey area or sampling frame. (If they were the same size then the count would become a census.) The total number, or density, of birds within the survey area is then estimated (along with associated variance estimates) by extrapolation from the numbers counted within the searched plots. Plot sampling methods are not used extensively for birds. The assumption that all objects or individuals of interest are detected with certainty within plots is usually unrealistic when applied to bird populations, particularly if the species of interest is highly mobile or not all birds from the population are available to be counted at a point in time (e.g. when female parakeets or mohua are incubating within nest cavities). However, these methods are applicable to some large, surface-nesting bird species such as albatrosses and counts of burrows made by seabirds such as petrels. When the assumption that all objects or individuals of interest are detected is violated, this method defaults to an index of individuals, occupied nests, burrows and sign.

Assumptions

- All birds (or related objects of interest such as occupied nests or active burrows) within the survey plots (i.e. the covered region) are able to be detected and counted.
- Plots are distributed over the area of interest or sampling frame according to some sort of probability-based design (simple random, stratified random, systematic with random start, etc.) and are of a shape, size (not necessarily equal) and number suited to the particular species and study (see Thompson et al. 1998).
- The bird population remains demographically closed (or at the very least constant) throughout the survey period.

Advantages

- Variance is usually estimated with respect to survey design (i.e. the number of plots, the way the plots are distributed within the area of interest, stratification, etc.). In the case of design-based variance estimates, survey design is known and therefore variance estimates are generally free from assumptions.
- Inferences about distribution (in addition to those about abundance) can be derived from model-based inference. This requires the collection of auxiliary habitat data on plots (usually recommended anyway) so that distribution models can be fitted.
- Model-based inference can improve precision (providing assumptions are valid).
- Non-parametric bootstrap variance estimation is robust to violations of the assumption requiring uniform and independent distribution of birds.

Disadvantages

- If not all birds or related objects of interest are detected, abundance estimates will be negatively biased.
- If design-based methods are to be used, then the survey design has to introduce randomness into plot selection to provide unbiased abundance estimates.
- Design-based inference is seldom possible for wildlife population abundance estimation because birds are often highly mobile and/or cryptic, and often some model-based inference is necessary to estimate *p.* This only becomes a problem when the first assumption is not met.
- Model-based inferences will be biased if the assumptions of the model are inappropriate. Assumptions need to be verified as far as possible.

Suitability for inventory

Plot sampling requires that all birds or related objects of interest within defined areas are counted. Resource costs (labour and money) can be significant and the data obtained are often beyond those required for simple inventory. For this reason, plot sampling within a study area is not recommended as a way of compiling simple species inventories.

Suitability for monitoring

Provided all assumptions can be met and sufficient resources are available, plot sampling can provide accurate and precise estimates of the size of a population of birds or related objects of interest in a much broader sample area. Plot sampling methods can be applied in a variety of ways to bird populations or related objects to estimate abundance. Conventional quadrat sampling might be used to estimate the density of nesting seabirds or their burrows (Gibbons & Vaughan 1998).

Alternatively, the plot might be a rectangular strip in which all birds are counted by an observer walking from one end to the other (Giradet et al. 2001). Circular plots of a fixed radius are also used to count birds, even though it is unlikely, particularly in densely vegetated habitats, that all birds within the plot will be detected. In practice, plot sampling of bird species that are either mobile, move away from observers prior to detection, are cryptic or inhabit densely vegetated areas should be treated as estimates of relative abundance, which may be sufficient if the aim is to examine temporal trends (see Giradet et al. 2001 for a practical summary of the problems).

Even though point estimates derived from plot sampling have high potential accuracy and precision, especially where sampling is stratified, great care still must be taken when using this information to detect population trends. Two sources of variation are important: Firstly, the sampling variation or the uncertainty surrounding the population estimates (usually expressed as the standard error of the estimate); and secondly, process variation, which covers the temporal and spatial variation in the population dynamics process associated with environmental variation (temperature, rainfall, etc.) and chance events and their impact on population demographics (e.g. temporal variations in population density) (Thompson et al. 1998).

Skills

Practitioners must be:

- Familiar with the relevant design issues pertinent to plot sampling. These include definition of the sampling frame, selection of size, shape and number of plots, as well as the means by which plots are distributed over the study area. Some idea of the species' spatial distribution (uniform, clumped or territorial) and potential for stratification is also extremely useful and can markedly improve the precision of abundance estimates. A pilot study incorporating assessment of statistical power will assist with these choices.
- Familiar with the target species (identification, behaviours, preferred habitats, etc.).
- Sufficiently mobile to cover the intended sample area within a stipulated time frame.
- Consistent about following the designated sampling design.
- Able to identify violations of assumptions and the consequences for calculated abundance and variance estimates.
- Trained in relevant analytical tools, or have access to advisors with specialist statistical skills and experience with the analysis programmes used to generate realistic abundance and variance estimates.

Resources

Although only a portion of the study area or sampling frame is covered when undertaking plot sampling, it is still assumed that all birds (or nests, etc.) are detected within each plot, i.e. a complete count of all objects of interest is conducted within each plot. Whilst the area needing to be surveyed is greatly reduced by using plots, complete counts at any scale are expensive, particularly if the target species or other objects of interest are mobile and density is low to moderate.

Equipment requirements vary depending on what is being counted, but can be categorised in terms of what is required to:

- Define or identify the plots—maps, GIS information, GPS, measuring tapes, previous location instructions, etc.
- Record the number of birds or related objects in each plot—a good pair of eyes, notebook, pen or pencil, camera or other field-based data-entry device, well-trained staff
- Move between plots—pair of legs or vehicles of various descriptions
- Analyse and store the data—appropriate data entry and storage systems, plus analytical facilities, such as relevant computer programs

Minimum attributes

Consistent measurement and recording of these attributes is critical for the implementation of the method. Other attributes may be optional depending on your objective. For more information refer to 'Full details of technique and best practice'.

DOC staff must complete a 'Standard inventory and monitoring project plan' (docdm-146272).

Minimum attributes to record:

- Record metadata, including observer's names and contact details, location (see next bullet point), date of survey, time over which the survey was conducted, weather details during survey period. The use of standardised, pre-tested data sheets throughout the sampling programme is recommended.
- Record location (eastings and northings and/or polygons) of the survey area, sample area, plot or sample name or reference, stratum (if design is stratified).
- Record habitat variables associated with each plot and stratum, if relevant to your objectives.
- For each plot, record the number of target species or related objects of interest seen, individual marks (e.g. band combinations), demographic attributes or other covariates that may help explain presence, absence and numbers (e.g. presence of nests, juveniles, breeding behaviours), position within the sample plot if necessary, and amount of time spent surveying each plot.
- Tally the total number of birds (individuals, pairs, etc.) or related objects seen within each plot in the sample area. It may be useful to plot the location of individual birds.

Data storage

Forward copies of completed survey sheets to the survey administrator, or enter data into an appropriate spreadsheet as soon as possible. Collate, consolidate and store survey information securely, also as soon as possible, and preferably immediately on return from the field. The key steps here are data entry, storage and maintenance for later analysis, followed by copying and data backup for security.

Summarise the results in a spreadsheet or equivalent. Arrange data as 'column variables', i.e. arrange data from each field on the data sheet (date, time, location, plot designation, number seen, identity, etc.) in columns, with each row representing the occasion on which a given survey plot was sampled.

If data storage is designed well at the outset, it will make the job of analysis and interpretation much easier. Before storing data, check for missing information and errors, and ensure metadata are recorded.

Storage tools can be either manual or electronic systems (or both, preferably). They will usually be summary sheets, other physical filing systems, or electronic spreadsheets and databases. Use appropriate file formats such as .xls, .txt, .dbf or specific analysis software formats. Copy and/or backup all data, whether electronic, data sheets, metadata or site access descriptions, preferably offline if the primary storage location is part of a networked system. Store the copy at a separate location for security purposes.

Analysis, interpretation and reporting

Always seek statistical advice from a biometrician or a person(s) experienced in analysing similar data before undertaking any analyses. That said, if the assumptions for plot sampling can be met, in particular, that all birds or objects of interest in the covered region are counted, then the analysis is relatively straightforward and the abundance estimates will be reliable. All uncertainty associated with abundance estimates stems from incomplete coverage of the study area.

A design-based approach is appropriate when plots have been selected randomly as part of a probability-based survey design. The number of birds or related objects seen in each plot is simply totalled then extrapolated to the wider survey area by dividing by the fraction of the survey area that was sampled (Imber et al. 2003). Appropriate variance estimates can then be calculated. (There are numerous estimators described in the literature that can be used this way. Good sampling theory texts include those by Thompson et al. 1998, Borchers et al. 2002 and Williams et al. 2002.) The major advantage of this design-based approach is its validity regardless of the processes affecting the spatial distribution of birds or related objects throughout the study area, provided the assumptions of the method have been met (Borchers et al. 2002).

Interpretation of resultant abundance estimates and trends within and between study sites should be approached with caution. Detailed statistical analysis of population trends requires specialist skills to assess the contribution of spatial and temporal variables (population dynamics, spatial distribution, environmental factors, etc.) that may not be apparent at first glance. Conservation managers should seek appropriate advice on the best approach.

A first step would be to simply plot the calculated abundance or density estimates (with appropriate variance measures) and examine this graph for any obvious trend. Further analysis might involve more complex model-based inference, e.g. use of analyses of repeated measures where the focus is on change over time in response to treatments (e.g. changes in kiwi-call count rates after pest control) (Williams et al. 2002).

Authors must ensure that results are reported regularly and in a timely manner (particularly if the monitoring programme is a long-term one) and in a format suited to the intended audience. This will ensure that analysis effort is spread throughout the monitoring programme and will ensure feedback and the continued interest of all participants. All survey participants should receive a copy of the report.

Case study A

Case study A: plot sampling used to estimate the number of grey-faced petrels breeding on Moutohora (Whale Island)

Grey-faced petrel, Moutohora (Whale Island) (photo: R. Slack).

Synopsis

Imber et al. (2003) estimated the population of the grey-faced petrel (*Pterodroma macroptera gouldi*) breeding on Moutohora (Whale Island), eastern Bay of Plenty, to be between 30 000 and 40 000 pairs of breeding birds. This estimate was based on data collected between 1968 and 1972, specifically on the numbers of fledglings banded during large-scale banding operations between 1969 and 1971, the proportions of fledglings found to be banded towards the end of those operations or among those recovered around the Whakatane region, and the percentage of burrows producing fledglings in a breeding biology study.

Considerable predation of petrel eggs and chicks by introduced Norway rats (*Rattus norvegicus*) and burrow destruction or disturbance by rabbits (*Oryctolagus cuniculus*) was noted between 1972 and 1987. These pests probably contributed to a decline in the petrel breeding population, reducing the population to a low point around 1987, possibly less than 35 000 breeding pairs. Both pests were eradicated between 1985 and 1987. A reassessment of the breeding population of the petrels following elimination of rats and rabbits was made between 1998 and 2000. This case study explores that breeding population reassessment as reported by Imber et al. (2003).

Objectives

- What was the breeding population of grey-faced petrels on Moutohora following the eradication of Norway rats and rabbits?
- Had the petrel population increased since the initial population estimate?

Sampling design and methods

The surface area of Moutohora was divided into 16 sections (Fig. 1) comprising uniform topography and vegetation. In essence, this was a form of stratification but it was not described as such (see '<u>Limitations and points to consider</u>' below). The area of each section was measured using an aerial photograph, then corrected for slope. The density of burrows was calculated within 2 m radius plots at 20 m intervals along a transect crossing the widest part of each section. At each interval, a plot was measured to the left and right of the transect line at 5 m centres off the line. In addition, several more-intensive 10 × 10 m plots were established within one of the sections as a comparison with the 2 m radius plots. Only those burrows that had been completed and were suitable for breeding were counted.

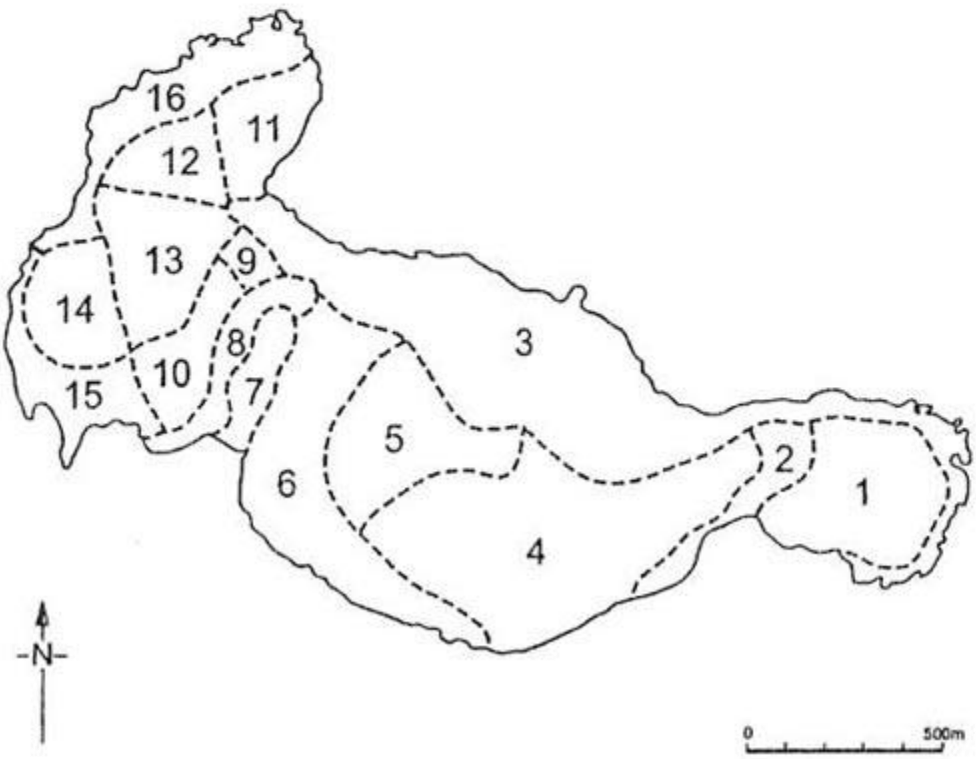

Figure 1. Moutohora (Whale Island) sampling sections (strata) (from Imber et al. 2003).

Data collection

An example of a data sheet suitable for collecting the required information is provided in Table 1. Information is provided for the first seven plots on a given transect.

Table 1. A data sheet from the Moutohora (Whale Island) study by Imber et al. 2003.

Date		**Observer**		**Section Slope**	20 deg.
1 May	1998	MJI		**Section Aspect**	North
Section #	1	**Section Area (ha)**	14.98	**Section Vegetation**	Pohutukawa Forest
Transect Easting	**Start Northing**	**Transect Bearing***	**Plot Number**	**Plot Area (m^2)**	**# Breeding Burrows**
1234567	7654321	180	1	12.57	2
1234567	7654321	180	2	12.57	7
1234567	7654321	180	3	12.57	8
1234567	7654321	180	4	12.57	0
1234567	7654321	180	5	12.57	1
1234567	7654321	180	6	12.57	4
1234567	7654321	180	7	12.57	2

*All bearings to be in degrees relative to grid north

Results

The number of burrows in each section was estimated using the following formula:

$$\hat{N} = \frac{A_S B_r}{12.5664(P_r)}$$

Where

A_s = area of each section measured in m^2

B_r = total number of burrows in all plots within a section

12.5664 = the area of a 2 m radius circular plot (in square metres)

P_r = number of plots counted in each section

Table 2. Estimated numbers of burrows suitable for grey-faced petrel breeding within the 16 sampling areas on Moutohora (Whale) Island (from Imber et al. 2003).

Section		**Burrows**	
No.	Area	Density (m^{-2})	Total (n ± SE)
1	14.98	0.034	5100 ± 900
2	4.43	0	0
3	57.60	0	0
4	37.39	0.090	33 500 ± 2 800
5	14.24	0.224	31 900 ± 2400
6	19.96	0.116	23 100 ± 1700
7	4.56	0	0
8	4.68	0.040	1900 ± 300
9	1.44	0.058	800 ± 200
10	6.63	0.021	1400 ± 300
11	11.17	0	0
12	6.29	0.036	2300 ± 400
13	11.28	0.047	5300 ± 900
14	7.09	0.043	3100 ± 500
15	8.50	0.001	100
16	19.69	0	0
Total	229.93		108 500 ± 10 400

For each estimate ($\hat{N}$), the standard error was also calculated and the results rounded to the nearest 100. The results indicated that within the 230 ha covered by the 16 survey areas a total of 108 500 ± 10 400 burrows were present. This estimate of c. 95 000 breeding pairs of grey-faced petrels, given an estimated burrow occupancy rate of 87% (where occupancy is defined as the proportion of burrows in which an egg was laid), suggests that the population has more than doubled since the 1969–71 breeding seasons following the removal of rats and rabbits by 1987. The counts also showed that burrow density was uneven. Five of the sixteen counted sections had no or very few burrows (Table 2) largely as a result of the physical properties of the areas (slope, thin soil, volcanic activity or sand dunes). The burrow densities calculated using the more intensive 10 × 10 m plots in Section 6 were very similar to those derived from the 2 m radius plots (0.1167 burrows m^{-2} compared with 0.1146 burrows m^{-2} in the 2 m radius plots).

Petrel recovery on Moutohora appears to have been uneven. Areas of optimal habitat retained the most burrows and breeding pairs, and produced the most fledglings at the population's lowest point because the detrimental effects of rats and rabbits were least at these locations. Following pest removal, the recovery of the petrel population within these areas was substantial for the first 10 years, then appeared to slow as the amount of available habitat for new burrows declined. In less-optimal habitat, recovery may have been slower, particularly in those parts most affected by rats and rabbits. It is thought that petrels are still increasing in these areas and that the increase may have been proportionately higher than in the more optimal habitats, given the abundance of ground space.

Overall, the population of grey-faced petrels on Moutohora is expected to continue to increase but at a lesser rate. The authors of the study recommended that another survey using the same methods be conducted in 10–15 years' time.

Limitations and points to consider

As petrel burrows have fixed locations and are detected with certainty within each plot ($p = 1$), the observation model is therefore known and the general design-based approach used in the above example is entirely appropriate. This means that model-based inference is unnecessary and variance estimates will be robust and assumption-free. This is obviously a major advantage and was possible because of the relatively large and obvious burrow entrances made by the petrels and the ability of observers to determine which burrows were definitely breeding burrows. Note that the estimates derived were for the number of breeding birds rather than an overall population for the Moutohora colony.

The key assumption of design-based estimation relevant to this study is that randomness (simple random sampling or systematic sampling with a random start) is introduced in the survey design when selecting plots to be searched. A single transect placed subjectively along the widest axis of sampling sections (in this case sections are analogous to strata) would appear to provide room for sampling bias. If this has been done (and we are not told the precise reason) to avoid the edges of the habitat units (sections), the edges will be under-sampled. This, of course, would not be a problem if burrow density is uniform within each section (or stratum), but the authors state that burrow densities only 'appeared to be relatively uniform'. It would be better if the design had been such that we did not have to make this assumption about burrow density.

We therefore have to conclude that what was essentially a stratified-systematic sample has been compromised by some unknown, but probably small, degree by the non-random starting point and transect orientation (i.e. an invalid probability-based sampling scheme). Another weakness of the design related to variance estimates—the paper did not explain how the standard errors were calculated and no variance estimates were provided for burrow occupancy.

References for case study A

Imber, M.J.; Harrison, M.; Wood, S.E.; Cotter, R.N. 2003: An estimate of numbers of grey-faced petrels (*Pterodroma macroptera gouldi*) breeding on Moutohora (Whale Island), Bay of Plenty, New Zealand, during 1998–2000. *Notornis 50*: 23–26.

Full details of technique and best practice

Plot sampling can be used in a variety of forms to estimate the abundance of birds. Arguably the method is best applied using direct counts of relatively sedentary populations of birds or indirect counts of related objects such as nests and burrows. In these circumstances plots are usually squares or elongated rectangular strips, a number of which are laid out using some sort of probability-based sampling design in the area of interest and within which all objects of interest are counted. This method is particularly useful where the objects of interest, including birds themselves, occur at high densities, are easily detected and are unlikely to move in response to the observer prior to detection. Application of plot sampling to relatively mobile bird species, using circular plots, for example, is more problematic. The chances of detecting all birds within the plot are low particularly if the habitat being surveyed is densely vegetated and/or the birds are cryptic or tend to flee observers. Such counts are better employed to estimate trends in relative abundance.

Obviously then, the way plot sampling is employed to count birds (directly or indirectly) will vary depending on circumstance (species, habitat, distribution, etc.) and a generic guide to best practice is therefore impractical. Nevertheless some general guidelines are possible:

- Survey objectives should be carefully considered, including whether you want to assess the entire population or just the breeding population.
- A probability-based sampling design (using random sampling, systematic sampling, stratified random sampling, etc.) should be used to maximise inference and provide accurate variance estimates.
- Sampling design, size, shape and number of plots should be tailored to the anticipated distribution and density of the population to be counted.
- The variance of population estimates must be calculated according to the sampling design employed.
- Every attempt must be made to ensure that all objects of interest within the plot are counted (p = 1). This can be extremely difficult for birds that inhabit densely vegetated areas, are highly mobile, and/or are sparsely distributed.
- All observers should be capable of identifying the target species or the objects of interest relating to the species' presence. If burrows or nests are being counted, observers must be able to distinguish occupancy or use from inactive sites and whether they were constructed by the target species.
- If remeasurement of plots in the future is considered likely some thought should be given to the permanent marking of plots.

References and further reading

Borchers, D.L.; Buckland, S.T.; Zucchini, W. 2002: Estimating animal abundance: closed populations. Springer-Verlag, London. 314 p.

Gibbons, D.W.; Vaughan, D. 1998: The population size of Manx shearwater *Puffinus puffinus* on 'The Neck' of Skomer Island: a comparison of methods. *Seabird 20*: 3–11.

Giradet, S.A.B.; Veitch, C.R.; Craig, J.L. 2001: Bird and rat numbers on Little Barrier Island, New Zealand, over the period of cat eradication 1976–80. *New Zealand Journal of Zoology 28*: 13–29.

Imber, M.J.; Harrison, M.; Wood, S.E.; Cotter, R.N. 2003: An estimate of numbers of grey-faced petrels (*Pterodroma macroptera gouldi*) breeding on Moutohora (Whale Island), Bay of Plenty, New Zealand, during 1998–2000. *Notornis 50*: 23–26.

Sutherland, W.J. (Ed.). 2006: Ecological census techniques: a handbook. 2nd edition. Cambridge University Press, Cambridge. 336 p.

Thompson, W.L.; White, G.C.; Gowan, C. 1998: Monitoring vertebrate populations. Academic Press, San Diego. 365 p.

Williams, B.K.; Nichols, J.D.; Conroy, M.J. 2002: Analysis and management of animal populations: modelling, estimation and decision making. Academic Press, San Diego. 817 p.

Appendix A

The following Department of Conservation documents are referred to in this method:

docdm-146272	Standard inventory and monitoring project plan