Birds: incomplete counts—line transect counts

Version 1.0

This specification was written by Terry Greene in 2012.

Contents

Department of Conservation
Te Papa Atawhai

Synopsis

Line transect sampling involves an observer travelling along a designated line of given length recording the number of birds, nests or other relevant objects (e.g. burrows, droppings and footprints) detected (Buckland et al. 2001; Gibbons & Gregory 2006). By moving all the time it is possible to cover large areas and generate large sample sizes more efficiently than when using other more elaborate methods such as point counts (see 'Birds: incomplete counts—five-minute bird counts'—docdm-534972) (Bibby et al. 2000; Buckland et al. 2001). Objects of interest can be recorded within a strip of known width, as counts of objects at any distance from the line or at measured distances from the line (i.e. 'Birds: estimates of absolute density and abundance—distance sampling'—docdm-534993). Strip transect sampling is simply an extension of simple line transects into plot sampling methods (Giradet et al. 2001). It assumes, significantly, that all birds or objects of interest within the strip are detected. In densely vegetated habitats this often necessitates the use of very narrow strips, but this can be very inefficient as many birds will be detected beyond the strip and ignored (Williams et al. 2002). Accurate visual assessment of strip width whilst moving along a line can also be very difficult and prone to bias.

Simply counting all individuals, groups, species and related objects of interest along a line can provide much useful information on the relative abundance of a population, provided appropriate sampling design and analysis principles are followed and the assumptions inherent to measures of relative abundance are met (see 'A guideline to monitoring populations'—docdm-870579). Although such counts are often viewed as a 'census' or 'population count', they are really indices because not all birds present will be detected, and an unknown number will remain hidden in surrounding vegetation. Surveys based on such indices are attractive as they are less expensive and require less effort than more formal estimation methods (Williams et al. 2002), and a range of simple indices can be calculated from the data (e.g. birds per km, number of groups per transect). However, indices generally yield weaker inferences because of uncertain and/or untested relationships between indices and actual abundance, untested assumptions of homogeneity of detection probability across time and space and, often, poor sampling design (Thompson et al. 1998; Williams et al. 2002; Gibbons & Gregory 2006). Although indices can provide much important information about the relative abundance of a population and, indeed, may be the only viable survey option, decisions on their use should be based on the relative importance of cost versus inferential strength (Williams et al. 2002).

Line transects are very adaptable and are suited to surveys of terrestrial, aquatic and marine environments. The method is particularly suitable for bird species that are highly mobile and conspicuous, occur in low density populations, have patchy distributions (provided sampling is adequate), or inhabit extensive, homogeneous, open habitats (such as grasslands, oceans, lagoon sand-flats and open water). However, the flexibility with which the survey method can be applied, combined with the limitations of indices, also means comparison of studies is extremely difficult. Although there are no universal rules for line transects counts, careful consideration needs to be given to sample size, sampling layout, optimal transect length, travel speed, number of visits to each sample unit and observer bias.

Assumptions

- Line transects are distributed over the area of interest according to a probability-based sampling design (simple random, systematic, stratified, etc.). This is particularly important when the distribution of target species is thought to be patchy or clumped.
- If the index is being used for comparative purposes, detection probabilities need to remain consistent across time and space, i.e. it is assumed that a constant fraction of individuals (direct counts) or sign (indirect counts) is counted between areas at the same time, between areas over time, or within an area over time.
- The total number of birds counted is consistently and linearly correlated with the actual density of the population.
- If the index is being used to estimate a parameter (e.g. absolute v. relative abundance), then the index will have been calibrated so that an unbiased estimate can be calculated. (Such use occurs rarely.)
- Birds are equally detectable on each sampling occasion.
- Birds are not knowingly double-counted.
- The population remains demographically closed throughout the survey period.

Advantages

- Line transects are extremely flexible, efficient and cheap as they require relatively little time and equipment.
- Line transects are particularly suited to sampling large areas of relatively open homogeneous habitat and species that are mobile, large or conspicuous.
- The method is particularly useful for monitoring bird populations that occur at low densities.
- Multiple species can be counted at the same time.
- Double-counting of birds is a relatively minor issue as observers are moving continuously.
- Birds are less likely to be attracted to a moving observer than a stationary one.
- In addition to walking, transects can be surveyed using ships, aircraft and cars.
- An index of relative abundance may be the only type of count method that can be applied in a given situation.
- May be sufficient to describe basic biological patterns.
- May be useful for comparative inference if the assumption about equal detection rates is met.

Disadvantages

- As most birds are detected and identified by call, high levels of observer skill and experience are required to identify birds accurately whilst on the move. When observers change between years, there is a risk the index will change as a result of observer variability rather than real changes in the relative conspicuousness of birds.
- Bird abundance and conspicuousness vary seasonally, with weather conditions, time of day and between species. Trends can only be detected reliably when transects are undertaken at the same time of year, at similar times of day (0800–1200 hrs and 1600–1800 hrs) and under similar

weather conditions for a given species. Comparisons between species are problematic, even when data have been collected as part of a multi-species survey.

- The requirement for similar conditions for all transects means that transects are best undertaken only in fine weather.
- Relative abundance can only be estimated because not all birds will be visible (e.g. identifying birds often depends on hearing them, so quiet birds high in the forest canopy can be missed), and no attempt is made in this method to adjust for variation in detectability.
- Although many factors that affect detectability can be controlled by standardisation of methods and sampling design (e.g. season, time of day, observer, species, effort), many factors (breeding status, density, etc.) cannot.
- Line transects may not be particularly suitable for highly mobile species because of the double-counting risk, those that are small or cryptic, or those that inhabit densely vegetated and/or rugged terrain. For example, random allocation of line transect routes can be difficult in some habitats and for some types of terrain.
- Assumptions of indices of relative abundance derived from line transects are rarely examined.

Suitability for inventory

Provided line transects sample a representative portion of the area of interest, the method is a relatively efficient means of compiling inventories of more conspicuous bird species. Large areas can be covered quickly and efficiently, and rarer species are more likely to be detected with this method than with point counts. However, the potential for bias introduced by observer variability, the cryptic nature of some bird species, vegetation density and topography need to be carefully considered. An inventory of forest bird populations was successfully conducted over a large area of southern South Westland using a combination of five-minute bird counts (point counts) and line transects between points (O'Donnell & Dilks 1986; see also O'Donnell & Dilks 1988).

Suitability for monitoring

Depending on study objectives, line transect counts repeated in a standardised manner over many years can provide information on changes in status and trend in numbers of birds, provided:

- The first three assumptions (at least) can be met (see 'Assumptions' section above).
- The implications of not meeting these assumptions (i.e. the amount and direction of bias) for the conclusions of a monitoring programme are understood.

Multiple counts on > 10 transects each year at a site will improve precision. One-off counts (e.g. annual counts) are common practice, but are unlikely to detect small changes in populations over relatively short time frames.

The power of this method is greatest when transects are repeated annually over relatively long time frames (> 10 years), when sample sizes (i.e. number of transects) are high, and when variation in observers, times of day and conditions are minimised.

Skills

Those responsible for survey design must be familiar with the design issues pertinent to the use on bird populations of relative indices of abundance derived from line transect methods (Buckland et al. 2001; Williams et al. 2002). These include the critical assumptions and their impact on appropriate sampling design, definition of the sampling area, sampling units, and number of lines (and their length) within the sampling area. An understanding of the target's spatial distribution (e.g. clumped or territorial) and potential for stratification is also extremely useful and can markedly improve the precision of abundance estimates. A pilot study is strongly recommended (Thompson et al. 1998). It will provide useful information on the precision resulting from a given level of effort and the likely encounter rate (i.e. power). This will also provide an estimate of the required effort to reach predetermined levels of precision.

Field observers must be:

- Very familiar with target species (identification, behaviours, etc.) as the observer will be constantly on the move
- Consistent in how they follow the designated sampling design and rules of the sampling method
- Able to identify possible violations of assumptions and the consequences for index estimates

Those responsible for analysis must understand the:

- Limitations of the data collected
- Potential impact of bias on calculated estimates
- Importance of calculating realistic variance estimates
- The most appropriate analyses and reporting format for the results

Resources

As line transects are relatively simple (at least for terrestrial surveys), the equipment needed is straightforward. The requirements are:

- Sufficient suitably trained people (especially in bird identification)—those not meeting a minimum standard should be excluded from the survey
- Maps of sample line or point distribution
- Marked lines (GPS location and/or tagged site)
- Binoculars
- Data sheets and a clipboard, notebook, pencils
- A watch
- A means of moving between plots—a pair of legs, or vehicles of various descriptions (see below)
- Appropriate safety and first-aid procedures and gear

As noted earlier, design skills are also important: Care is required when designing the sampling programme to ensure the critical assumptions underlying indices of relative abundance are met and sufficient data are collected.

Aerial surveys are usually only an option for large bird species that inhabit open terrestrial and aquatic habitats. These surveys require aircraft that can fly slowly, are manoeuvrable, provide unrestricted forward and downward visibility and have sufficient range and capacity. Marine or freshwater shipboard surveys require a stable viewing platform with sufficient height above water to maximise visibility. Vessel size, speed and noise produced will also influence suitability. These considerations, along with those relating to observer safety, invariably inflate cost and resource requirements.

Sufficient resources should also be set aside for the cost of data entry, analysis and subsequent reporting of results—costs that are often overlooked when formulating a monitoring programme.

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:

- Study information: Record where, when and why the study was undertaken, the location of the study area (polygon) and the sample area, the precise methods used, where the data are stored and access arrangements.
- Station information: Record location (eastings and northings and/or polygons) of the survey area, sample area, transect lines and strata (if required). Note line length and sample effort (number of times any given line transect is walked). Habitat variables associated with line transect and stratum can also be recorded.
- Observation information: Record the observer's name and contact details, date of survey, time over which it was conducted (start/finish times) and weather details (rain, cloud, wind, temperature, sunshine minutes, noise—see Dawson & Bull 1975 for suitable categories).
- Count information: Record number of target species (or objects of interest such as nests and burrows) seen or heard from the line. If the target species occurs in flocks, obvious pairs or other relatively tight aggregations (i.e. clusters), the number of individuals within the cluster should be recorded as accurately as possible. It is also useful to record relevant covariates (e.g. treatment, non-treatment, forest type).
- Enter data into an Excel spreadsheet (as column variables). Use separate worksheets for details of sampling layout and other explanatory material (i.e. metadata). An example of the minimum data requirements and layout is provided in 'Case study A'.

Data storage

Forward copies of completed survey sheets to the survey administrator and enter data into a suitable format (Excel 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, along with copying and data backup for security.

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

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

Seek statistical advice from a biometrician or suitably experienced person prior to undertaking any analysis.

Results are best summarised in a spreadsheet (e.g. Excel). Columns in the spreadsheet should include all data recorded on the field sheet because the influences of factors such as location, observer and weather need to be accounted for in any analysis.

In most circumstances, statistical comparisons should only be made once several years of data are collected. The power of this method is greatest when transects are repeated annually for a long time (> 10 years). These counts are often viewed as a ‘census’ or ‘population count’. However, in reality they are indices because not all birds present are detected. An unknown number can remain undetected or hidden in surrounding vegetation. A range of simple indices can be calculated (e.g. birds per km, number of groups per transect) then reported and discussed along with appropriate measures of variance (e.g. standard errors, 95% confidence intervals, etc.). Comparisons between years for the same sites are appropriate, but fixed line-transect counts should not be used for comparison with other sites.

Detailed statistical analysis of population trends requires specialist skills; conservation managers should seek advice on the best ways to analyse counts. Because it is not possible to standardise all aspects of surveys between years, statistical modelling procedures are used to distinguish between variation in counts resulting from differing environmental or sampling conditions and variation in the actual number of birds observed. Multiple regression models (generalised linear models) provide a suitable, though potentially complex, means of analysing trends.

Case study A

Case study A: monitoring mohua (yellowhead) 1983–1993

Mohua (yellowhead) (photo: Michael Eckstaedt).

Synopsis

In response to concerns about declines in mohua (*Mohoua ochrocephala*) in the mid-1980s, counts of mohua were conducted for up to 10 years (1983–1993) to determine the species' status at 12 sites that were important for this species, (O'Donnell 1996). Counts were conducted by members of the New Zealand Wildlife Service (later Department of Conservation), the Forest Research Institute and some private individuals with appropriate expertise.

Objectives

- Which mohua populations were declining, which were stable and which ones might be increasing?

Sampling design and methods

Monitoring was planned for 10 years at 12 sites. A practical and easily repeatable monitoring method was required because monitoring sites were geographically dispersed and often remote, and each site would have different observers. A standardised data sheet was drawn up to be used by all observers (see Table 1). Trend analysis was undertaken using Poisson (discrete) regression.

Table 1. Standardised data sheet used to collect survey data for mohua.

Place:	Blue Mountains		**Observer:**		Graeme Elliott	
Date:	1/11/07		**Rain:**		None	
			Wind:		Calm	
			Temp:		Cool	
			Cloud:		4/8	
	Time					
Transect	**Start**	**Finish**	**Group**	**No. of birds**	**Males**	**Females**
1	10:00	10:30	1	2	1	1
			1	3	2	2
			1	4	1	1
			1	1	1	0
2	10:45	11:15	1	2	1	1
			1	3	2	2
			1	4	1	1
			1	1	1	0

Results

Fourteen populations at 12 sites were monitored for up to 11 years (O'Donnell 1996) (see Table 2). Between 1983 and 1993, one population became extinct and 5 of the 14 populations declined significantly. Three of these were on the verge of extinction by 1993. One population increased, and seven did not change significantly, although a declining trend was recorded in five of these. Six population crashes coincided with irruptions of stoats (*Mustela erminea*) following heavy beech seeding.

Table 2. Numbers of mohua, detected on standard transects in 14 populations, 1983–1993. A hyphen (-) denotes no count in that particular year. Trend: + = increase, – = decrease, * = significant change.

	1983	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**Trend**
Mt Sokes	-	-	6	5	4	1	3	9	4	13	11	+
Hawdon Valley	31	35	40	34	14	12	12	10	4	3	5	–*
Poulter Valley	-	-	-	72	-	-	43	-	1	0	-	–*
Windbag Valley	-	2	6	3	2	0	0	0	0	0	1	–*
Landborough Valley	-	-	163	-	-	-	-	-	24	14	-	–*
Dart Valley 1	-	-	-	-	-	-	-	34	12	26	22	–*
Dart Valley 2	-	-	-	-	-	-	-	18	8	11	-	–
Eglinton Valley	-	28	41	32	30	23	17	22	12	19	16	–
Burwood Bush	-	-	4	10	6	3	2	0	0	0	0	extinct
Waikaia Bush	-	-	12	0	6	4	-	6	-	3	4	–*
Blue Mountains	-	-	31	37	57	76	78	62	57	86	60	+*
Catlins 1A	12	-	11	-	-	7	-	-	10	10	11	stable
Catlins 2A	4	-	4	-	-	5	-	-	-	6	6	+
Rowallan	-	-	-	48	32	31	-	-	-	12	-	–

Use of results

Prior to the monitoring programme it was thought that mohua were secure. The results highlighted that the species was now endangered throughout its range; mohua were declining in remote areas that were not threatened by habitat loss, and introduced predators were implicated in declines.

Counts in future years

Monitoring using transects continued during subsequent years and in some areas experimental predator control was undertaken (O'Donnell et al. 1996; Dilks et al. 1996). In these intensive study areas, counts on transects complemented more intensive banding studies and territory mapping. Ongoing monitoring confirmed the significant trends of decline identified after the initial 10 years. In addition, declines continued at three sites where the initial decline had not been statistically significant. One site that was increasing declined subsequently (O'Donnell et al. 2002).

Limitations and points to consider

Counts were not achieved in all areas in all years, reflecting difficulties in setting up consistent monitoring at a large number of sites. Replication of counts was only achieved at a couple of sites because of difficulties of maintaining effort at the full range of sites over subsequent years. This lack of replication of sample units (i.e. transect lines) at each site makes calculation of realistic variance estimates next to impossible. It is a serious flaw within the sampling design. At a minimum, 10 (but preferably no fewer than 20) replicate lines should be surveyed at least once at each site to provide the basis for calculating the variance of encounter rates and the construction of confidence intervals (Buckland et al. 2001). Repeat surveys of one or two lines within a single site and within each survey period (temporal as opposed to spatial replication) should be discouraged.

Transects should also be selected and located within the sample area according to some form of random probability sampling (simple random, systematic, stratified random, etc.) that ensures adequate representative sampling coverage over the area of interest. Transects placed subjectively (e.g. 'to sample the best habitat', etc.) should be avoided. If this cannot be done (because of topography, cost, time, etc.) great care will be required when interpreting the results because of the significant risk of biased results. Sampling effort (i.e. number of surveys on each transect and length of line transects) should be considered in terms of the level of precision required. It is best addressed through a pilot study and appropriate power calculations.

However, despite these flaws, the line transect counts were still able to detect changes in mohua populations. This is largely testament to the long time frame over which the counts were conducted, combined with the dramatic changes (usually marked declines—often in the order of > 80% over 10 years) in populations of mohua over the study period. It could also be argued that the sites themselves were the sampling units and that consistency of pattern across all beech forests surveyed was just as informative as the details on population changes for each site. Nevertheless, it is extremely unlikely that the method as described would be as successful detecting much smaller rates of change.

References for case study A

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Full details of technique and best practice

Line transects can be used to derive simple indices of relative abundance. That said, provided the critical assumptions can be met (or any failures and their impact recognised), the potential sources of bias identified and the likely power of the resultant inferences understood, line transects can be a useful means for monitoring population change. This approach is most appropriate when change over time is expected to be large, the degree of inferential strength required is relatively low and resource constraints are significant. As a general rule of thumb, line transects are best employed (and are most efficient) in open and uniform habitats occurring on easy terrain where birds are easily detectable (mobile, large, or conspicuous species) and/or where the species of interest occurs at a low density.

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

- Survey objectives should be carefully considered and explicitly defined (consider scope and focus—Are you measuring the entire population or just the breeding population? Are you using direct counts of birds or an indirect measure based on burrow density? Are you aiming to assess the impact of a management action? Will the programme be one of long-term monitoring? Is an estimate of relative abundance sufficient? etc.).
- The population of interest must be carefully defined in both time and space. What will be sampled? Where will it be sampled? When will it be sampled (when the birds are most sedentary, territorial, conspicuous, or all of these)?
- A random probability-based sampling design should be used to maximise inference and provide accurate variance estimates (random sampling, systematic sampling, stratified random sampling, etc.). Sampling design, length, number and layout of lines should be tailored to the anticipated distribution and density of the population to be counted. The extent of sampling effort needed and how it will be allocated spatially (e.g. whether stratification is needed) and

temporally must be specified relative to the degree of precision required. A pilot study may be required if no other information exists.

- A minimum of 10 (and preferably at least 20) replicate lines should be surveyed to adequately estimate (a) the variance of encounter rates and (b) appropriate confidence intervals.
- The variance of population estimates must be calculated according to the sampling design employed.
- A sampling protocol specific to the monitoring programme being conducted should be written. This should explicitly state:
    - objectives
    - sampling design, including details of line and point lay out (particularly if counts are to be repeated on a regular basis), and allocation of observers to transects, etc.
    - observer training requirements
    - data collection rules (e.g. speed at which transect should be traversed, rules for dealing with groups of birds, whether the observer may leave the line)
    - minimum data requirements
    - guidance on completion of provided data sheets
- All observers should be capable of identifying the target species (by sight and/or calls) or the objects of interest relating to the species' presence. If indirect measures (such as burrows or nests) are being counted, observers must be able to distinguish occupancy or use (e.g. old nests v. active nests) and whether they were constructed by the target species. A comprehensive training programme is required. Minimum standards (i.e. performance criteria) for observers may need to be instituted.
- Every attempt must be made to ensure that the main assumptions of indices are met. This can be extremely difficult for birds that are highly mobile, inhabit densely vegetated areas and/or are either sparsely distributed or extremely common. Practitioners should be prepared to discuss potential failures of assumptions and the impact those failures might have on estimates of relative abundance.
- Analysis of data should proceed with caution. Results of reporting should be comprehensive and include details of sampling variances and the impact of any measured covariates (e.g. observers). Examples of measures that can be reported per transect (or unit distance travelled) are: total numbers of species, total number of groups, total number of territorial males, number of a species encountered.

References and further reading

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Appendix A

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

docdm-534993	Birds: estimates of absolute density and abundance—distance sampling
docdm-534972	Birds: incomplete counts—five-minute bird counts
docdm-870579	A guideline to monitoring populations
docdm-146272	Standard inventory and monitoring project plan