Distance sampling

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CONTENTS

Abstract

Animal abundance survey methods that do not incorporate a probability of detection (e.g. the five-minute point count) have to be used under strictly standardised conditions, and therefore have limited application. However, distance sampling methods estimate a probability of detection, rely on few assumptions, and can be conducted in the form of both line and point transects. The assumptions for distance sampling can be reasonably met through training, effective field techniques, and appropriate field design. Possibly the greatest disadvantage to these methods is the minimum number of detections (60–80) which are likely to be necessary for fitting the detection function. However, because the same number of detections is required for both very large and small areas, distance sampling methods can also be very efficient. It is therefore recommended that the Department of Conservation consider incorporating distance sampling into its monitoring and assessment programme. General recommendations with regard to this, and specifically to the field trialing of distance techniques, are presented at the conclusion of this report (sections 7 and 7.1).

Keywords: distance sampling, bird counts, population density, line-transect, point-transect, New Zealand

1. Objectives

The need to prioritize the investment of finite conservation effort and dollars, while also achieving effective management of our remaining avifauna, means that decision-makers require reliable estimates of abundance that can be produced cost-effectively. Accurate distribution and abundance information is required for categorising threatened species, directing early intervention where appropriate, and for testing and illustrating the outcomes of management initiatives. Distance sampling techniques potentially provide a range of tools, for providing such estimates of abundance.

This document has been researched and written for the Department of Conservation to provide a basis for discussion regarding distance sampling techniques, and whether these could be usefully incorporated into the Department's bird monitoring and assessment programmes. An introduction to distance sampling and the assumptions on which these techniques are based is presented. This is followed by a brief discussion regarding the use of line-transects and point-transects, a recommended form for the point-transect count, a brief overview of the standard five-minute count in New Zealand, and selecting between absolute and relative survey methods. Suggestions are also made regarding the way that distance sampling may be incorporated into the existing five-minute count regime. Recommendations are presented at the conclusion of this report.

Within the following text, older studies that have used a distance criterion have been cited because they are useful in assessing the degree to which critical distance sampling assumptions have been met under a range of field conditions (Buckland et al. 1993). However, recent studies which have used current distance methods after Buckland et al. (1993) and analysis via a version of the Distance programme, have been used where possible.

2. Terminology

The terms point-transect and line-transect refer to distance sampling that is conducted at a point or along a line. The term point-transect was coined to refer to distance sampling at a point, as the point could be considered to be a transect of zero length (Buckland et al. 1993).

The term point-count is used to refer to a stationary, relative density count that is conducted at a point. Such a count does not incorporate a distance criterion or any form of a probability of detection for the surveyed subjects. In the context of this report, this term refers to the relative density counts that have been historically conducted in New Zealand. These counts have usually been of five-minute duration.

3. Brief introduction to distance sampling

The term 'distance sampling' refers to a suite of methods that will estimate the absolute density of biological populations, based on accurate distance measurements of all objects near a line or point. Distance sampling is an extension of plot sampling, where it is assumed that all objects within sample plots are counted (Buckland et al. 1993). However, the advantages of distance sampling include the following:

- Estimation of the absolute density for a population, even when not every individual is detected per unit area.
- The same estimation of density for a population can be calculated from data collected by two different observers, even if one of these observers misses a lot of subjects away from the line or point.
- Only a relatively small percent of individuals need to be detected within the sample area, possibly as few as 10–30%.
- The size of the sample area can be unknown.

Central to the concept of distance sampling is the 'detection function'. This is the probability of detecting an object, given that it is at any distance y from the random line or point. This distance y refers to either the perpendicular distance for line-transects or the sighting (radial) distance for point-transects. Generally the detection function decreases with increasing distance (Buckland et al. 1993). This is illustrated in Figure 1.

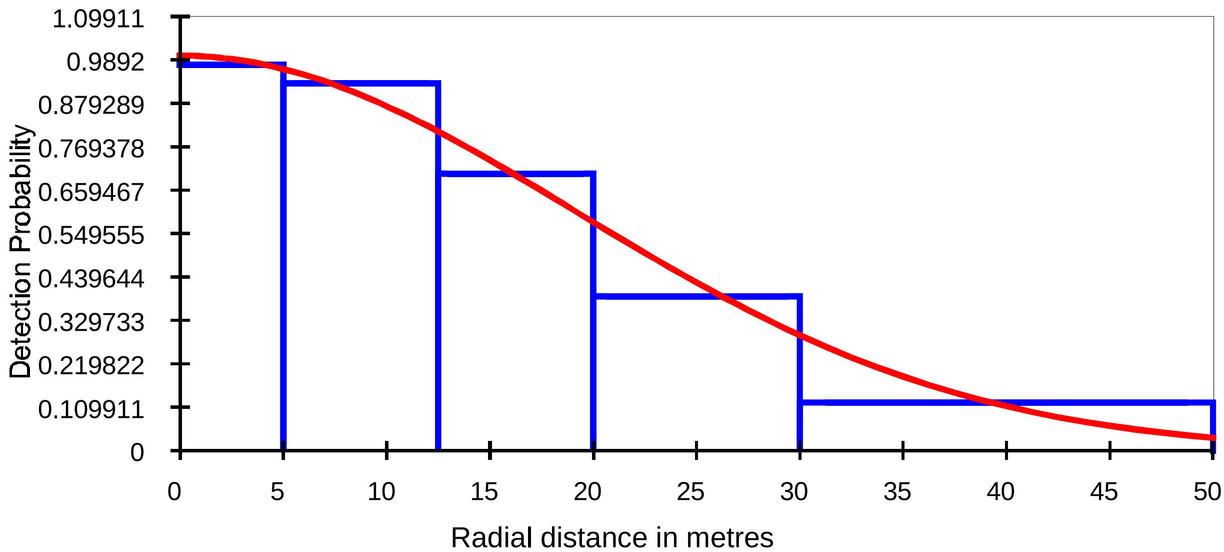

Figure 1. An example of a detection probability plot as generated by the analytical program Distance 3.5 (Thomas et al. 1998). In this example, the probability of detection has dropped to 50% between 20 and 25 m distance from the observer.

Distance sampling techniques have proven effective for sampling a huge range of fauna, from butterflies (Brown & Boyce 1998) and birds (Oliveira et al. 1999; Catt et al. 1998) to chameleons (Jenkins et al. 1999) and benthic stream fishes (Ensign 1995). They are also highly adaptable; for example Manly & McDonald (1996) briefly described adaptations to the line-transect for the purposes of sampling polar bears (*Ursus maritimus*) by helicopter. The techniques are predominantly based on line and point-transects. However, variations include the trapping web, such as that used by Corn & Conray (1998) for estimating the density of mongooses (*Herpestes javanicus).*

Detailed information regarding the theory behind distance sampling is presented in the book 'Distance sampling: Estimating abundance of biological populations' (Buckland et al. 1993). Instructions for field design, examples of application, and some comparisons between point-transects, line-transects and mapping census techniques are also presented in this text.

Also of interest is Cassey's MSc thesis (1997), from the University of Auckland, and the papers since developed from this (Cassey & McArdle 1999; Cassey & Ussher 1999). Cassey (1997) explored the application of distance techniques on two New Zealand species, the North Island saddleback (*Philesturnus carunculatus rufusater*) and the northern tuatara (*Sphendon punctatus punctatus)*. He also presented a summary of his thesis results in a report for the Department of Conservation, entitled 'Estimating animal abundance: An assessment of distance sampling techniques for New Zealand populations'.

Analysis of distance data is via the programme Distance (the current version of this programme is No. 3.5, Release 5, Thomas et al. 1998), which provides a range of models that have been proven to perform well in the analysis of distance data. This programme and the book Distance (Buckland et al. 1993) are both available free from the internet, on the Distance home page at:
http:/www.ruwpa.st-and.ac.uk/distance/

3.1 ASSUMPTIONS UNDERLYING DISTANCE SAMPLING

Distance methods are designed to produce reliable estimates of abundance regardless of varying conspicuousness, provided that the assumptions are met (Buckland et al. 1993). The three key assumptions, on which distance sampling are based are:

- Objects on the line or point are detected with certainty.
- Objects are detected at their initial location.
- Measurements are exact.

Furthermore, it is necessary that the transects (points or lines) must always be positioned randomly within the study area. However, all the assumptions may be relaxed under certain circumstances (Buckland et al. 1993).

The three key assumptions are discussed individually in the following sections, as distance sampling cannot be effectively implemented if these assumptions are unable to be reasonably met. Indeed, Dawson & Bull (1975) and Dawson (1981a) have already expressed doubt about meeting the three key assumptions in New Zealand forests. These concerns related to the issues of undetected birds located overhead of the observer, inaccurate estimates of distances to heard birds in forests, and the movement by some species towards or away from the observer.

3.1.1 Detection of all subjects at zero distance

As mentioned above, either the lateral or radial distance from the observer to the subject is the measurement necessary for distance analysis, regardless of how high or low that subject is within the structure of the habitat. Subjects are therefore recorded as though located on a single plane with the observer, or both angle and direct distance information is collected and these measurements are later converted into lateral distance information for analysis. When sampling birds in forested habitat the assumption that all subjects are being detected at zero thereby generally refers to those subjects right above the observer, on or close to the line or point. Therefore, a problem can arise when plant forms such as dense epiphytes and lianas obstruct view (Karr 1981). Also, when vegetation is high and the birds are small the observer may have to rely on vocalisations as a cue to bird presence (Karr 1981), as well as take a period of deliberate searching time to determine presence or absence of species. Two large New Zealand avian species, that may also present a problem when meeting this assumption, are the kereru (*Hemiphaga novaeseelandiae*) and kaka (*Nestor meridionalis septentrionalis)*, due to their sometimes-cryptic nature.

If the observer does fail to detect birds on or close to the line or point this will cause an underestimation of density. However, there are potential solutions for most situations. For example, a count for kereru that lasts for at least ten minutes provides an opportunity for undetected birds to reveal themselves by moving. Long counting periods can erroneously result in an overestimate of density, due to birds moving within or entering the transect during the count. However, this problem is unlikely to arise with this species, because of the noise made by kereru when moving. Potential solutions for kaka could include stationing a second observer at some distance to the primary observer, with the job of scanning trees overhead of the primary observer, and close to the point. However, if one were to use this approach one would also have to be cautious of developing bias due to guarding the centre of the point or line (Buckland et al. 1993).

Cassey & Ussher (1999) encountered this issue of non-detection at zero, when surveying the nothern tuatara (*Sphenodon punctatus punctatus*), because of the likelihood that some tuatara may have been underground on or close to the line. Due to this problem, it was considered that the resulting densities were likely to be an underestimate. No attempt was made to estimate the number of animals that may have been missed, and then correct for this factor. However, when the densities derived from the distance survey were compared to those calculated from a simultaneously conducted mark and recapture exercise, there was no detectable difference between the results. Furthermore, perhaps the most important outcome of the comparison of these two methods was that the distance sampling survey was found to be more time-efficient and less stressful on the animals and the environment than the mark and recapture survey.

In comparison, Southwell (1994) also failed to record all animals on or close to the line due to a 'counting saturation' effect, when surveying tame populations of Australian macropods. This saturation effect at high densities resulted in a small negative density-dependent bias in the relationship between estimated density and true density. However, in this study, the bias was considered to have been small enough to have little practical consequence. Within a New Zealand context, such a saturation effect may become a factor when surveying high densities of species such as the bellbird (*Anthornis melanura*). However, very high densities of birds are relatively rare on mainland New Zealand due to our conservation problems. Furthermore, it is recommended that point-transects rather than line-transects, are used when dealing with high-density populations (Buckland et al. 1993).

If it is known in advance that a species will be problematic, with respect to detection at zero, and, if one can independently estimate how many subjects were likely to have been missed on the point or line, a correction factor can be easily included in the analysis to accommodate this.

In practise, detection at or near the point or line should be nearly certain, and this consideration should be paramount when designing the survey (Buckland et al. 1993). Therefore all possible steps should be taken to ensure that this criterion is fulfilled and the pilot survey serves an important role in achieving this.

3.1.2 Subjects are detected at their initial location

If undetected movements of subjects are random, then no serious problem will result, provided such movement is slow with respect to the observer (Buckland et al. 1993). When conducting point-transect counts this assumption can be partially met by not including birds that either fly over the plot, or enter the sample area during the count (Marsden 1999; Buckland et al. 1993). Generally, little is generally lost by the exclusion of these individuals (Buckland et al. 1993). However, any movement whatsoever is obviously going to be fast in relation to a stationary observer conducting a point-transect. Theoretically, the objective of a point or line transect is to record the number of subjects present at a single moment in time, and the position of these subjects in relation to a random point or line. Therefore to achieve this while minimising the amount of movement by the subjects during the course of the count, point-transects should be conducted as 'snapshot' counts (refer section 4.1).

The issue of movement by some species towards or away from the point or line in response to the observer is primarily a problem when it is undetected, and happens before the observer can record the location from which the subject moved. For instance, flushing can aid detection as long as the point from which the bird has emerged can be pinpointed. Alternatively, in a non-forested habitat, or in a marine situation, the use of a second observer and double-platform counting can adequately account for this (Borchers et al. 1998). Unfortunately, in forested habitat and with a species that is frequently very strongly attracted to people, it can be impossible to detect a bird with certainty before it has reacted to any observer. An example of one such species is the North Island robin (*Petroica australis longipes*). Until further investigations have established the consequences of violation of this assumption by this species, it would seem wise to be conservative and avoid using distance methods on the North Island robin, and other such species known to exhibit strong reactive behaviour before detection.

Major movement towards the observer will overestimate densities, while movement away from the point, or line will generally reduce the densities. If it hasn't already been revealed in the field, movement away from the observer prior to detection can sometimes be recognised when data is scrutinised in the form of histograms (Buckland et al. 1993).

Problematic movement towards or away from the observer has been recognised in a number of studies and can sometimes be attributable to field design. For example Pyke (1983) found movement away from the observer to be a problem in his point-transect study on Australian honeyeaters, due to the observer using a ladder as a sampling platform, and the observer regularly moving up and down alternative sides of this. In fact, in this instance the disturbance to the birds was such that only relative count data were finally utilised in the analysis of this survey. Gutzwiller & Marcum (1997) found a number of North American bird species to respond to brightly coloured clothing, and considered that if such reactions were not taken into account they could potentially violate assumptions of distance sampling.

Once a disruptive field technique has been identified it can often be avoided or corrected. For example, when Conant et al. (1981) surveyed two Hawaiian bird species when comparing line and point-transects, they found that one species moved towards a moving observer, while the other species moved towards a stationary observer. In another case, Southwell (1994) encountered reactive movement away from the observer in wild populations of Australian macropods, which he suggested could be mitigated by a faster means of traversing the transect, or perhaps the development of a correction factor. It is thereby critical to tailor field methods and survey design to help ensure that this assumption of detection at the subject's original location is not violated. Again, the pilot survey provides an opportunity for discovering and dealing with such problems.

Distance sampling can also be usefully utilised for inanimate objects such as nests, leks, burrows, or pellets. Obviously, violation of this assumption is not a problem in such surveys.

3.1.3 Measurements are exact

'The accurate measurement of distances is essential to any accurate estimate of bird density' (Scott et al. 1981) and, as such, is fundamental to the effective implementation of distance methods. However, concern has been expressed regarding this assumption in relation to recording birds that are only heard, rather than seen, in forest. This is because the estimation of distance by sound is affected by many factors. These include the hearing ability of the observer, the training the observer has received, the level of the observer's fatigue, characteristics of the habitat, time of day, background noise, the type and duration of the bird-calls or song, the direction that the bird is facing when calling, the direction that the observer is facing, and the terrain (Scott et al. 1981). Many of these potential sources of bias can be mitigated by training and good field methods. However, factors such as hearing ability or birds reacting in a problematic way to the observer can not be resolved in this way.

The hearing ability of the observer is a basic consideration in any bird survey. Ramsey et al. (1981) recommended testing the hearing of observers, to increase their comparability, after large differences in hearing ability among active birders indicated differences in the area effectively surveyed, as large as an order of magnitude. Hearing ability obviously also has to be adequate for the study species in question, for example a high frequency species such as the rifleman (*Acanthisitta chloris)* may be undetectable to some observers.

The direction in which a bird is facing whilst calling will affect the volume of the call. One assumes that birds will be randomly orientated to the observer. However any tendency for the study species to turn towards the observer when calling could potentially lead to problems of underestimate of density due to increased volume (Scott et al. 1981).

Observer competency has frequently been cited as an important variable (Buckland et al. 1993; Kepler & Scott 1981), and training is the logical solution to most cases of observer related bias (Faanes & Bystrack 1981). In fact, poorly trained observers can present a problem that is potentially more difficult to deal with than hearing loss (Faanes & Bystrack 1981).

Scott et al. (1981) also strongly emphasised the benefits of training, informing and having motivated observers. They recommended that all observers be trained under a regime starting with estimation of distance to stationary seen objects and working up to birds that are heard but not seen. Such training could utilise both recorded and real calls from known distances. Training devised by Kepler and Scott (1981) started with identification of individual species and worked up to finally introducing the observer to distance estimation. This training continued until ±10% accuracy was reached. This level of accuracy was found to be achievable by Scott et al. (1981).

The degree to which the attentiveness of the observer can impact on the quality of data is such that fatigue or physical discomfort should be minimised whenever possible (Emlen & DeJong 1981). Emlen and DeJong went so far as to suggest that three to five hours of full attentiveness on a survey route is apparently close to the maximum for most observers. Cassey (1997) found distance techniques to be robust against the differences in morning and afternoon bird conspicuousness. However, sampling at a time when the study species are most vocal will optimise on good quality survey time and effort, while gaining the highest possible number of detections. For many species, this optimal time will be a period during the morning.

Of the physical factors affecting survey accuracy, Karr (1981) considered weather and topography to be the two most important. However, the acoustic properties of habitats also vary. Within open fields the primary sources of degradation are attenuation and amplitude fluctuations. However reverberation is possibly the most sever problem for song recognition and localisation in a forest (Richards 1981). Scattering and reverberation can result from the presence of trunks, foliage, and the ground (Richards 1981). The detection threshold distances are also different per species, and these thresholds differ according to factors such as wind (Emlen & DeJong 1981). Therefore, it is important that at each new study site, time is taken for familiarisation and poor weather conditions should be avoided.

When Dawson & Bull (1975) originally expressed concern regarding this issue of ‘exact measure’ they were referring to a standard of accuracy described by Emlen (1971), of “equivalent to a good 6-inch range finder”. Obviously such accuracy would not be possible in forest, when dealing with birds that are heard rather than seen. As an alternative, this potential problem of inaccurate estimation of distance in forest can be mitigated by the use of distance intervals, rather than exact distances per subject.

The cut-points for distance intervals will necessarily have to be determined on-site, so that they are appropriate for the sample area. Such intervals would quite possibly vary and be unique for each individual study, as appropriate. It has been considered beneficial to match interval categories with natural rounding tendencies of the observers (e.g. 50, 100, etc.) (Scott et al. 1981), as long as training and testing in the field have shown these to be reasonable. Scott et al. (1981) also strongly recommend the flagging of visible interval boundaries, to aid demarcation. This was done by Cassey (1997), who demonstrated the successful use of line-transects in vegetation that was sometimes very dense, and Barraclough to aid demarcation of intervals in tall mainland forested habitat (unpubl. data). However, the use of rangefinders is naturally recommended whenever possible (Buckland et al. 1993; Scott et al. 1981).

Intervals will generally be larger with increasing distance from the observer (Figure 2). The number of intervals should also be as numerous as practicable in the field.

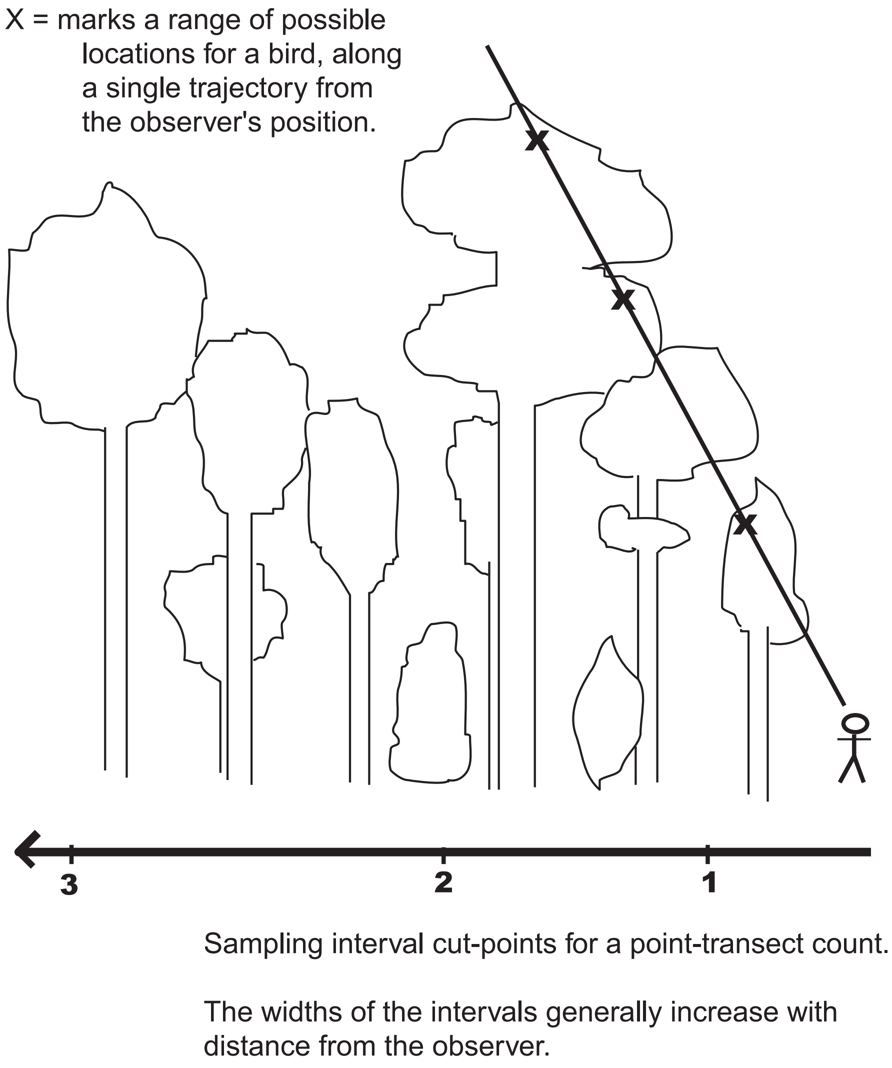

Figure 2. Depiction of interval cut-points designed to try and minimise confusion in determining the distance of a heard, but not seen bird.

In conclusion, it is important to note that reliable estimates of density may still be possible even if this assumption of exact measurement is violated, as long as errors are not near the line or point, as the accuracy of these are crucial (Buckland et al. 1993). Small errors in detecting birds close to the observer can seriously bias density estimates (Verner 1985). Potential data errors include mismeasurement, either under or overestimation of distances, or rounding-off measurements to convenient or favoured figures (heaping). If errors away from the point or line are not to affect density estimates, they can only be randomly attributed rather than systematic. Systematic bias in data collection is problematic in analysis. Again, the pilot survey offers the important opportunity to check the data for any signs of sampling bias by the observer.

3.1.4 Other considerations and limitations

A requirement of distance techniques is that they need a reasonable number of detections for adequate analysis (Marsden 1999). It is recommended to aim for at least 60–80 sightings, for fitting the detection function (Buckland et al. 1993). If sightings are lower than this, one becomes more vulnerable to stochastic factors, for example if there are only a total of 20 sightings and there happened to be a spike of detections close to the track, or point by chance—such a spike would be problematic in analysis. However, if the data is of very high quality, then reliable estimates may possibly be obtained from smaller samples.

It should also be emphasised that distance methods are highly efficient for large regions. This is because the same number of detections (60–80) are required for an estimation of density within a large region, as are needed for a small region. Furthermore, it should also be noted that if all lines or points have been surveyed, and not enough detections were recorded, it is not necessary to add further lines or points to the sample design. This is because the number of detections can be acceptably increased, by recounting existing lines or points (Buckland et al. 1993).

Only quality data can produce reliable estimates of density. This cannot be emphasised enough. To this end both training and a pilot survey are imperative. The role of the pilot survey, in assuring that the assumptions of distance sampling have been reasonably met, has been stressed in the previous sections. However, the pilot study also exposes any logistical and other practical problems, whilst providing preliminary data useful for helping to estimate the effort that will be required to obtain the minimum number of detections for the survey. The pilot study data can also be used for power analysis, which can assist in determining the effort that will be required to achieve the desired level of precision. However, it is always important to remember that because of the small amount of data that is generally available from a pilot study, power analysis can also be highly misleading.

With regard to analysing distance data, it is interesting to note the study by Anderson & Southwell (1995) on the training necessary to effectively analyse distance data. Anderson and Southwell presented data sets to newly trained 'students' and 'experts' for analysis. This was done in an attempt to explore the skill levels required to effectively analyse distance data, using the programme Distance, and also explore comparability of the analyses between participants. The data used in the experiment had been collected under an adequate design, and when assumptions were relatively valid. There proved to be little difference in the resulting analyses, produced by the participants. Therefore, Anderson and Southwell consequently considered that anyone with basic training could perform nearly as well as experts in the field of distance sampling analysis.

To conclude this section, it is interesting to note results from computer simulations conducted by Cassey & McArdle (1999). The computer simulations were used to test the capability of distance sampling to produce unbiased estimates of density on a range of changing distributions, densities and detection of animals across sampling areas and transects (primary sampling units). It was found that, given that the assumptions of distance sampling are not violated, distance sampling consistently gave accurate estimates of density. Furthermore, an overestimate of variance only occurred when most of the sample area was sampled and this was combined with a large between-transect variation. These results are reassuring in that distance sampling was proven to perform under a huge range of extreme scenarios.

4. Line-transects versus point-transects

Line-transect sampling is active, while point-transect sampling is passive. Thereby, lines can help detection of birds through flushing or disturbance, eg alarm calls (Buckland et al. 1993). Line-transects are recommended where populations are sparsely distributed, occur in well-defined clusters and low or medium cluster density (RUWPA 1999), or for large areas of homogenous habitat (Baillie 1991). Very mobile species are also likely to be surveyed more effectively through line-transects, rather than point-transects Buckland et al. (1993)

Point-transects are recommended for dense populations, or for multi-species surveys in forest habitats. Populations occurring in difficult terrain or on land where walking transects while expending effort to detect and record animals is problematic are also best done using point-transects (Buckland et al. 1993). Birds that occupy relatively small territories, and which are easily detected at close range, such as male songbirds of many species during the breeding season, may also be preferably surveyed by point-transects, especially in dense habitat (Buckland et al. 1993). They are also recommended for populations that occur in patchy habitats (Baillie 1991), where the objective is to relate the populations to each habitat.

Of the two methods, line-transects are more efficient, due to the fact that one is moving while sampling. In comparison, time walking between point-transect may be considered as effectively lost.

When evaluating point-transects, line-transect, mark and recapture, and roost surveys, Casagrande & Beissinger (1997) found all four methods to produce similar results. This is despite the fact that the number of points and lines that they used could reasonably be considered totally inadequate. (A total of eight point-transects which were divided up by habitat type, and a total of four line-transects). The mark and recapture method was found to be the least precise of the four methods.

The only comparison of line-transects and point-transects on a known population of a New Zealand avian species has been that conducted by Cassey (1997) on North Island saddleback (*Philesturnus carunculatus rufusater*). Unfortunately, in this instance, neither the one-minute or five-minute point-transect counts performed well in comparison to the line-transects. A number of factors may have contributed to this result. These could have potentially included an inadequate familiarisation period before the beginning of the count, movement of the birds during the count, or confusion over the size of family groups that were heard but not seen. The area covered by the line-transects was also substantially greater than that covered by the point-transects. However, the number of detections gathered from each of the two methods were numerous enough to plot a probability of detection, so this factor of different coverage may not have been problematic. This result will hopefully be revisited in a follow-up study that is planned for May 2000 (by Barraclough & Cassey), using a modified version of the point-transect as outlined in the following section (4.1) and a randomly placed grid of point-transects to compare with the re-sampled line-transects.

Neither line-transects nor point-transects alone are likely to perform well for all species in a community. However, well-designed line or point transect studies yield substantially more reliable comparisons across both species and habitats, than do straight counts of birds without distance data or other corrections for detectability (Buckland et al. 1993).

4.1 RECOMMENDED FORM OF THE POINT-TRANSECT AND COMBINING POINT-TRANSECTS WITH TRADITIONAL POINT-COUNTS

As previously stated, the theoretical aim of a point-transect (and a line-transect) is to sample the distance from all the birds present in the sample area to the observer, at a single given instant in time. Expressed in other terms, the ideal is to capture a ‘snapshot’ in time.

The balance is therefore to spend enough time at the point to fulfil the requirements of distance sampling, such as detecting all birds at and close to zero, while not over-extending the period of the count. If the counting period is too long then densities are likely to be overestimated, because birds move through the count area or are counted more than once (Baillie 1991).

Therefore, a recommended format is as follows. This is presented without times, as these will be dependent on species specific requirements:

- The observer approaches the point quietly.
- The observer waits for a period of time (the length of this time is discussed below) for activity to return to normal, and to familiarise her/himself with

what is happening within the sample-area. During this time the observer takes note of the location of birds and activity in relation to the distance intervals and of what is happening at and close to zero.

- A snapshot count is conducted (duration of count is species specific).
- If a bird has repeatedly called from a position before the count, but did not do so during the count then this individual may still be counted in the count. However, this can only be done if the observer can confirm the on-going presence of the same bird, by checking to see if it is still there after the count is finished. Obviously this can only be done if the terrain allows the observer to approach the location of the bird without taking too much time.
- Unless the forest is depauperate of birdlife, only species requiring a similar search criterion would be sampled per snapshot count, eg bellbirds and tui (*Prosthemadera novaeseelandiae*) could be sampled together.
- No bird flying over or through the sample area during the snapshot is included in the count.

A reasonably substantial waiting period is desirable. This should be at least a minimum of three minutes duration. The longer that the observer waits and learns about what is happening within the sample area, the better the snapshot count will be. (As long as the observers presence is not disturbing the birds.) If distance sampling were to be included in an on-going five-minute sampling regime then the snapshot count could fit in very well. For example, the snapshot count for mobile species would be conducted after the five-minute count, by which time the observer would be very familiar with the activity in the sample area at zero and in relation to the distance intervals.

The time that the actual snapshot count can take will vary per species. For mobile species the briefer the snapshot time period, the better, to avoid error due to the movement of birds during the count. Within tall forest, a duration of two minutes has been found to allow time for the observer to scan the complex structure around her/himself (R.K. Barraclough unpubl. data) and quickly record details.

However, as outlined previously, a snapshot count of ten minutes duration is not unreasonable for a kereru, due to their noisy movement through forest. Thereby distance sampling could easily be incorporated into present kereru ten-minute counting regimes.

The inclusion of birds that do not actually call within the time period of the snapshot, but have done so on more than one occasion before the count, is quite reasonable. However, this can only be done if the observer firmly confirms that the same bird is still *in situ* after the count has been conducted. As this can be a time consuming process, it will not always be cost-effective and some birds that are likely to have still been present at some distance from the point will have to be left out of the survey.

This approach to point-transect counting has many advantages. It aids in determining that all birds are detected at zero. It allows for the observer to become generally familiar with the sample area in terms of the distance intervals and then also the bird activity in relation to these intervals, and this helps to ensure that distances are accurate. This approach can also potentially be conveniently combined with on-going relative density counting regimes. Finally it also allows the observer to use all available information in the survey by including known birds which are only silent during the snapshot counting period.

5. Relative density bird counting in New Zealand

Traditionally, avian population surveys in New Zealand have concentrated on measuring relative density (e.g. Wilson et al. 1998; Pierce et al. 1993; Clout & Gaze 1984; Rasch & Craig 1988). Absolute density measures have generally only been attempted in crisis situations (Cassey 1997).

Relative density counts have been predominantly in the form of the standard five-minute count, which was introduced by Dawson & Bull (1975). This technique was developed as an easy means of producing an index of bird numbers for detecting major differences in bird abundance. It was designed for use when knowledge of the actual population was not needed, and is based on the assumption that the sample represents a constant but unknown proportion of the population (Bull 1981). The technique was promoted as an alternative when Dawson & Bull (1975) expressed concern about being able to meet the key requirements of distance sampling in New Zealand forests.

Dawson & Bull (1975) (and Dawson 1981) acknowledged that the number of birds recorded in these five-minute counts would be affected by a number of factors other than the number of birds present. These were cited as; individual observer bias; the change of each observer's skill through time; the changing conspicuousness of birds according to time of day, season and weather; the effect of weather on the observer; and the topography and density of the vegetation. Other declared potential sources of bias, also include factors such as observer fatigue, and sun-angle (Bollinger 1988). However, all of these factors undermine this major assumption of the sample representing a constant but unknown proportion of the population. This proportionality constant represents the probability of detection for subjects in the survey, and, as spatial and temporal comparisons of indices are generally crucial, it is necessary to also assume that this is constant over space and time (Pollock 1999). However, the estimation of detection probability over space and time has not been designed into these monitoring studies beyond attempts to standardise biasing parameter such as 'time-of-day'. An example of a combined approach to achieving this would be where index data were to be collected at all space-time points but absolute abundance estimates were also collected at some space-time points, for calibration (Pollock 1999).

The limitations imposed by the sources of bias, outlined above, mean that relative density results can only be compared with others obtained by precisely the same methods and usually by the same observer (Erskine 1981). For example, meaningful comparisons are not possible between very different habitats (Dawson & Bull 1975), and relative density methods would therefore be inappropriate to use in restoration projects, where a frequent objective is to actually achieve a major change in the structure and density of the habitat.

Obtaining meaningful data through the use of relative abundance counts takes careful planning. This is illustrated by the following example: Moynihan (1980) used five-minute point-counts for exploring the abundance of birds within a number of Northland forests, whilst acknowledging that bias due to conspicuousness would have affected the results. The paper also talks of the results providing an index. Some years later Pierce et al. (1993) repeated the counts in an endeavour to explore changes in these bird populations through time. Within this follow-up study, considerable effort was made to match the same weather conditions, dates, and times of day to those of the earlier survey, and they concluded that there had been an overall downward trend for kereru. However the same stage of fruiting and flowering phenology could not be duplicated. It was thought that this would not be a problem, due to the spatial extent of the surveys, and indeed it may not have been. However, Clout and Hay (1989) have also illustrated the influence that a favoured food source can have on the movement of this species (where a transmitter bearing pigeon spent 82% of its miro feeding time on a single tree, and total miro feeding time for this bird was 87%). Therefore, because movement effects conspicuousness, this potential source of bias alone was capable of causing major bias in index based results.

The impact of observers is also very powerful. Recher (1981) recognised this in the report from a working group on the need to standardise census methods. The subsequent guidelines for point-counts included the requirement that a single observer should always conduct a single point-count, and, that if different observers were used, then the surveys should not be counted as repetitions of the same point. It was recommended to consider such a repeated survey, conducted by a different observer, as if from another point altogether.

However, when all potential sources of bias are standardised, the five-minute standard technique can be useful for providing a range of information. This includes presence information for distribution, species diversity, changes in conspicuousness through seasons, time and between sites, and gross changes in populations. Five-minute counts and other relative indices can also be useful for addressing issues related to visitor experience in natural areas, due to the very reliance that these techniques have on conspicuousness. Therefore, the key issue to consider when determining whether a relative density sampling technique, without a probability of detection, should be adopted as opposed to an absolute density method is whether the technique can yield the necessary information for fulfilling the objective of the study.

6. Distance sampling (absolute density) versus relative density

Karr (1981) recommended that four primary questions should be asked and carefully considered before a survey is initiated. These four questions will be similar to those which are likely to be asked, as a matter of course, by the Department of Conservation whenever a survey is considered necessary, and are therefore not novel. However, it seems appropriate to include these within this report.

Karr's (1981) four questions for considerations are:

- Why? Why is the research programme being initiated, and what are its objectives?
- Who? What is the species to be surveyed, and how will its natural history characteristics affect the survey?
- What? What type of information is needed to attain the project objectives?
- How? What are the time, funding, logistical, and other restraints, within which the survey will have to work?

If distributional information or conspicuousness information is of interest, then relative density measures may be appropriate. Furthermore, if relative density comparisons can be made under circumstances that do not violate those sources of bias outlined in section 5, then such methods are acceptable. However, it is clear that the circumstances under which relative density surveys are suitable and worthwhile are likely to be rare.

Morin & Conant (1994) chose to select relative counts over absolute density counts for detecting gross population changes in a Hawaiian finch on a small island. This method was considered desirable as Morin & Conant (1994) had identified time of year, breeding and observer effects as the major sources of bias for their specific study. Therefore, they determined that strip transects conducted at a standardised time of year would probably be adequate to track the key result of interest, which was the gross change in population through time.

However, generally it is difficult to apply a relative density measure effectively. Gibb (1996) stated that 'when interpreting counts of forest birds it is seldom possible to distinguish the effects of changing density from those of changing conspicuousness: These often arise from the birds' singing and calling'. This was underscored by Moffat & Minot (1994) when they pointed out that because no estimation of detection distances is included in the five-minute point-count, differences in conspicuousness could account for most of the variability between species or seasons. Gibb (1996) suggested that indices of abundance based solely on the numbers first seen would probably track the numbers present more accurately than would those including birds first heard. However, even this approach was acknowledged as potentially biased as the use of a regular song-post can make some birds more visible. In confirmation of this Mehlhop & Lynch (1986) found that areas of high capture rates did not necessarily correspond with the locations of singing males, when comparing point-counts with mist-netting results.

Relative counts can be used to compare relative abundance while methods involving distance estimation must be used where estimates of density are needed (Verner 1985). If one recognises the need to incorporate a method that will calculate a probability of detection, then it seems most reasonable to use distance sampling, which is a proven technique. Furthermore the advantage of distance sampling over other non-relative methods such as mark and recapture is that it is also a comparatively non-intrusive and non-disruptive method.

The greatest drawback of distance sampling is the number of detections generally required (60–80). Due to this requirement, very small populations are unlikely to be effectively surveyed using distance sampling, where a high proportion of the population would have to be counted perhaps a number of times to yield enough data for the detection function.

Distance sampling methods are also obviously inappropriate where natural history characteristics of the study species mean that the assumptions are unreasonably violated. An example of this is the North Island robin, (given in section 3.1.2) which is frequently strongly attracted to an observer.

If distance sampling is to be widely adopted the necessary commitment to training and piloting distance surveys can not be stressed enough. There is little scope for manipulating distance data that has been collected in intervals during analysis. Therefore, any problems in data collection have to be picked up before the survey is conducted, in the pilot stage, and corrected. Furthermore, on occasion, the outcome of the pilot study may indicate that the required level of effort would not be cost-effective, and another survey technique may become the most efficient method of choice to meet the survey objectives.

Distance sampling appears to be most useful where reliable estimates of density are needed for comparisons between sites, through time, or for the investigation of a single population (e.g. stichbird, *Notiomystis cincta*, on Little Barrier Island) where the likely population size is large enough to obtain sufficient detections cost-effectively.

A number of recent studies have successfully utilised distance sampling on a range of terrestrial and marine species and in highly diverse circumstances. Some of these terrestrial examples are briefly outlined below: Marsden (1999) successfully used point-transects for estimating the densities of tropical parrots and hornbills in Indonesia. Buford et al. (1996) utilised line-transects to count fledglings in an endeavour to explore productivity of a range species. They found the line-transect to be less obtrusive and less labour-intensive than alternative mist netting or nest searching methods.

Childs et al. (1998) found distance sampling to be a relatively simple and adaptable method for estimating dog density following a mass canine rabies-vaccination campaign, and not prone to problems associated with meeting some model assumptions inherent to mark-recapture estimators.

Hein (1997) demonstrated the use of line transect surveys to estimate grey squirrel density and determine the costs of conducting surveys to achieve precise estimates. He found the line-transect surveys to be cost effective and to provide unbiased estimates of density, provided that the assumptions of distance sampling theory are not violated.

Corn & Conroy (1998) compared capture-recapture and distance sampling, in the form of live trapping-webs (an application of distance sampling where detection by an observer is replaced by the distance from the trap to the centre of the trapping web, Buckland *et al.* 1993), to estimate the density of mongooses. They determined that estimates of density based on mark-recapture depended heavily on assumptions about animal home ranges, and that those based on trap webs required few assumptions and that estimated variances from these may be more realistic. They also advocated this latter technique due to its ease, efficiency and reliability.

Finally, Brown & Boyce (1998) advocated line transect sampling for monitoring karner blue butterflies to avoid bias due to differences in site detectability. They also observed that their study species was less active on cooler days, and identified this as another source of bias for an index generating method.

In conclusion, distance sampling techniques represent a range of powerful tools, which could be of tremendous use to the Department of Conservation's monitoring and assessment programme. The effective incorporation of these techniques will be subject to the training of observers, the use of good sample design, and regular use of pilot surveys.

7. General recommendations

The author recommends that Department of Conservation consider taking the following actions:

- Incorporating distance sampling and analysis techniques into its avifauna monitoring and assessment programme.
- Taking full advantage of opportunities to field-trial distance techniques, along side other survey methods and on known populations.
- If the Department of Conservation decides that distance sampling techniques will be of substantial use, they consider sending a representative to a distance training workshop, or alternatively inviting a key distance sampling expert (e.g. Steven Buckland) to New Zealand to instruct DOC staff.
- The objective of a survey should always be the primary consideration when selecting between an absolute or relative density method.
- Methodological decision making could be aided by the development of guidelines for standard operating practices, based on considerations such as study objectives, characteristic species behaviour, terrain, and resources.

7.1 RECOMMENDATIONS FOR FIELD-TRIALING DISTANCE TECHNIQUES

- When utilizing distance techniques, primary focus should be placed on training, field techniques, and sample design.
- A pilot survey is always necessary for detecting observer or methodological problems, and for indicating the level of effort that is likely to be required to meet the study objectives.
- In the interests of efficiency, line transects should be used where possible.
- Where point-transects are appropriate, a snapshot count technique should be adopted. These snapshot counts can be conducted at the conclusion of a current five-minute count survey regime. However, for species such as kereru, a snapshot count can be the equivalent of a ten-minute count.

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