

# The Use of Global Positioning Systems to Record Distances in a Helicopter Line-Transect Survey

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## Abstract

Methods that allow unbiased estimation of animal abundance are increasingly demanded in management and conservation. The use of these methods should respect their assumptions. The need for accurate distance measurements in distance-sampling surveys is stressed. Here we present 2 alternative methods for measuring distance from a line to an object during helicopter surveys: 1) using a Global Positioning System (GPS) unit, with distances measured using appropriate software; and 2) recording declination angles and altitudes, using basic trigonometry to obtain the appropriate distances. These are compared to distances measured by a laser rangefinder (assumed to be true distances). The effect of the different errors on estimated densities is assessed by simulation. The GPS method appeared to be very accurate, while a potential downward bias in estimated density could be present if the inclinometer method is used. We discuss the implication for wildlife studies of using different measurement methods leading to different errors. (WILDLIFE SOCIETY BULLETIN 34(3):759–763; 2006)

## Key words

bias, distance sampling, Global Positioning System, GPS, helicopter survey, inclinometer, line transects, measuring distances, simulation.

The basic information for informed decision-making on management of a given population is the population size. Unbiased methods for estimating abundance are, therefore, invaluable. Distance sampling is one of the most widely used methods for estimating animal abundance (Buckland et al. 2001). In line-transect sampling, a large number of lines, covering the study area according to some random design, is sampled and the distances from the line to all the animals detected are recorded. The key idea is that the information contained in the detected distances can be used to model a detection function,  $g(x)$ , which represents the probability of detecting an animal as a function of its distance  $x$  from the line. This function allows us to estimate the probability of detection of a given animal in the covered area, unconditional on its position, and hence to estimate abundance using a Horvitz–Thompson-like estimator. The usual formula used for the density estimator is

$$\hat{D} = \frac{nf(0)}{2L}, \quad (1)$$

where  $n$  represents the number of detected animals,  $L$  is the line length, and  $f(0)$  is the estimated probability density function of the detected distances evaluated at 0. In line-transect sampling,  $f(x)$  is just  $g(x)$  rescaled to become a probability density function. The methods are well described by Buckland et al. (2001), and

recent developments, including the use of covariates other than distance for modeling the detection function, are dealt with by Buckland et al. (2004).

A key assumption in line-transect sampling is that distances are collected without errors. The effects of failure of this assumption have only recently been studied (Chen 1998, Marques 2004), and its violation is rarely tested in published studies. Although strongly discouraged, some studies still rely on poor methods for estimating distances, including eyeball estimates. However, with the improvement of field methods and technology, we believe that violations of this assumption will become less serious because in most cases there is no longer any reason to collect distances with significant errors. In some circumstances, such as marine mammal surveys, distance estimation remains problematic, despite recent work on distance-measurement methods (e.g., Gordon 2001).

The accuracy of Global Positioning System (GPS) as a way for mapping animal territories has recently been evaluated (e.g., Hulbert and French 2001), but its use for measuring distances in distance-sampling surveys has been overlooked. In this paper we present the methods used to estimate distances in a helicopter survey of polar bears (*Ursus maritimus*) that was carried out in August 2004 in the Barents Sea area. We used a GPS to collect waypoints that, once downloaded to a computer, allowed the measuring of the distances of interest. Previous similar surveys have used inclinometers for measuring angles (Wiig and Derocher 1999, Evans et al. 2003). Together with helicopter altitude, basic

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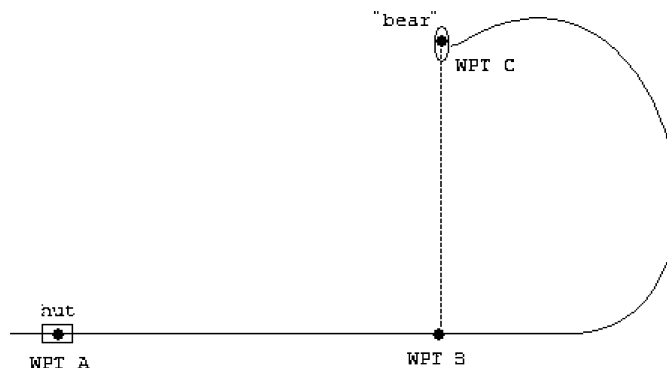
trigonometry yields distance estimates. We carried out a field trial to assess the accuracy of both methods. Using an observer at known distances from the line (measured by a laser rangefinder), we were able to compare the process of measuring distances using the GPS and the inclinometer. We present the results of a simple simulation study comparing the effects of the different errors found and discuss the implications of the results.

## Methods

### Field Methods

In the survey, we used a helicopter with 4 observers (the pilot was the front right observer) to fly systematic parallel line transects previously uploaded into a GPS unit (Garmin GPS76; Garmin International, Olathe, Kansas). The helicopter generally flew at about 61 m and 185 km/hour. Due to weather conditions, we sometimes used other combinations of altitude and speed. The left front observer held a second GPS unit. Every time a bear was detected, the observer took a GPS waypoint (WPT A). The pilot then tried to keep his bearing until the bear was abeam of the helicopter, when an observer took a second waypoint (WPT B), at which point the helicopter went “off effort,” to travel to the place where the bear had first been seen. The observer then took a third waypoint (WPT C). Altitude was recorded using the helicopter analogical instrument panel, and, when possible, a declination angle was taken using an inclinometer (Suunto, Vantaa, Finland). The GPS files were later downloaded to a computer. Using the software GPS Map Explorer version 2.34 (<<http://home.tiscali.no/gpsii/>>), 1 of 2 persons (T. A. Marques and M. Andersen) measured the perpendicular distance from the line to the bear, as well as the initial sighting distance. All distances reported in this paper are in meters.

We conducted a field trial on the island of Prins Karls Forland (11°35'E, 78°22'N) with 2 persons placed on the ground. These 2 persons and a small hut used for reference represented a right triangle (Fig. 1). The helicopter flew over the small hut, where WPT A was taken, then over the first person, where WPT B was taken, and a declination angle and the helicopter altitude were also recorded. The helicopter then left the line and hovered over the second person (acting as the bear), where WPT C was taken. This was done to mimic the real survey. Hereafter in this paper, the distances obtained using the GPS information are referred to as method A, while the distances obtained using the angle of declination and altitude are referred to as method B. The distance between the 2 persons was recorded by one of them using a laser rangefinder (Opti Logic Rangefinder 800XL; Opti-Logic Corporation, Tullahoma, Tennessee; accuracy  $\pm 1$  yard), referred to as method C. Both T. A. Marques and M. Andersen measured the distances from the field trial independently. We considered 10 different true distances (as measured by the laser rangefinder) between the line and the bear in the range between 50 and 400 m. In the analysis of the actual polar bear survey data, approximately 70% of the detected distances were smaller than 400 m. Because of bad weather, the field trial had to be terminated sooner than expected. This explains why, for some true distances, we took 2 or 3 WPTs at each point, allowing measurement of GPS consistency, while for others we took only 1 WPT.



**Figure 1.** The relative position of the waypoints (WPTs) recorded in a field trial to compare different methods of estimating distances from helicopter distance-sampling surveys. Waypoint A is taken when the helicopter is over the hut, WPT B when the helicopter is perpendicular to the “bear,” and WPT C over the “bear.” The solid line represents the helicopter flight path; the dashed line is the distance we are interested in measuring.

### Data Analysis

We compared the sets of measurements using method A, made by T. A. Marques and M. Andersen in the field trial, to test whether there was an observer effect in the measurement of distances. We used simple linear regression and correlation measures to compare the results of the 3 methods used.

### Simulation Experiment

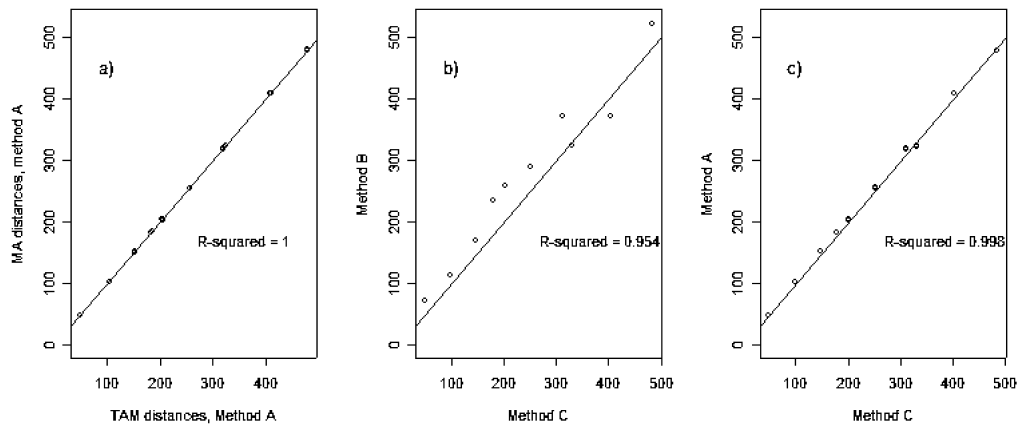
Considering the process that generates errors when distances are measured with a GPS, an additive error structure is expected (e.g., Chen 1998), of the form  $Y = X + R$ , where  $Y$  is the estimated distance,  $X$  is the true distance, and  $R$  is the error. As an example and for simplicity, we assume a Gaussian error model. Therefore, we estimate the mean and variance of the errors, comparing estimated distances using methods A and B with the true distances from method C.

We simulated data from the estimated detection function in the actual survey (J. Aars et al., Norwegian Polar Institute, unpublished data), a half-normal model ( $\hat{\sigma} = 423.2$ , corresponding to  $f(0) = 0.0019$ , with truncation distance  $w = 1,068$  m), with no adjustment terms, using sample size equal to the one observed in the survey (180 bears). These distances were then used to estimate  $f(0)$  with Distance 5.0 software (Thomas et al. 2004), using 1) the original simulated distances, 2) the distances contaminated with an error as in method A, and 3) the distances contaminated with an error as in method B.

We repeated these 3 scenarios 1,000 times each, and obtained mean  $f(0)$  and associated measures of precision using an automated analysis allowing the best of 3 models (half normal + cosine, hazard rate + simple polynomial, uniform + cosine) to be chosen by minimum Akaike information criterion. This allowed us to compare the effect of different distance-measurement methods in the final survey results, as bias in  $f(0)$  is proportional to bias in density, all other things being equal, as shown by equation 1.

## Results

The distances measured by each observer using method A are virtually the same (Fig. 2a). This was a reassuring result, as it showed it was unlikely that extra variation was being introduced



**Figure 2.** The perpendicular distances (to the “bear”) recorded in a field trial to compare different methods of estimating distances from helicopter distance-sampling surveys. (a) The distances measured independently by T. A. Marques and M. Andersen, (b) the distances as estimated from the inclinometer measurements versus the true distances, (c) the distances as estimated from Global Positioning System readings versus the true distances.  $R^2$  values are shown. The line  $y = x$  is plotted for reference.

by having several people doing the measuring step. Hence, in the following, we use only T. A. Marques’s measurements. The distances estimated by methods A and B are plotted against the true distances as obtained by method C (Fig. 2b,c).

The  $\bar{x}$  and SD of the errors associated with method A were respectively 2.3 and 5.1, while for method B they were 27.6 and 29.4. Therefore, it is clear that method A is much less biased and more precise than method B.

There is no difference between the results obtained analyzing the true distances and the distances contaminated with error under method A, while we observe a 10% downward bias in  $f(0)$  using distances estimated by method B (Table 1). While these results assume the estimated mean error is the true mean error, due to the small sample size, the precision on this estimate is low; the resulting bias in estimates might be larger or smaller, depending on whether the mean error is respectively higher or lower than the estimated value.

## Discussion

Given the results presented, the use of GPS for measuring distances means that the assumption of no measurement error was reasonably met in this distance-sampling survey of polar bears.

Any results obtained under a field trial should be looked at carefully, to ensure that no erroneous generalizations are made in a real survey situation. In this case, we believe that errors found under the field trial should be considered a lower bound to what the real errors might be. Detection of multiple animals at the same time, the need to keep searching for other bears after one is

detected, the fact that sometimes when detected the bear is already close to abeam, flying under less than optimal conditions, etc., are all likely to decrease performance under real-life surveys. In cases when a bear is observed just before it disappears from the view of the observer behind the helicopter, it is very difficult to take the declination and the data point is lost under method B. Such cases also might lead to difficulties in method A. If the bear is running, it is difficult to decide exactly where the bear was when it was observed. Taking WPT C under method A will, therefore, have a higher error under a real survey than under the experimental survey as reported here. However, all these factors are much more likely to impact on method B than on method A, and, therefore, the relative difference between these 2 methods is likely to be even more profound in favor of method A than what was found here.

Problems related to altitude measurement are difficult to deal with, as well as related errors due to ground slope. (In the trial zone, the ground was almost flat, which was not the case in most of the survey over land areas.) The helicopter had only an analogical altitude indicator, making it very difficult to distinguish between, for example, 45 and 52.5 or 52.5 and 60 m. Note that for an angle of 10 degrees, 45 m means 259 m horizontal distance, while 60 m means 346 m. It is likely that a better altitude recorder would improve on method B’s performance. Additionally, it often was the case that a declination angle could not be obtained for a given sighting (requiring an ad hoc “guesstimated” distance), or even if obtained, it was with much less precision than during the trial.

Although not taken into account in this study, it is likely that if

**Table 1.** Results of simulations performed to compare distance-sampling estimates obtained considering data from different methods of distance estimation, based on the results from a field trial. Mean estimated value of the probability density function of detected distances,  $f(0)$ , and number of model parameters ( $\pm$ SD) over the 1,000 simulations, for the model chosen by minimum Akaike information criterion for the original distances and distances contaminated according to the errors from method A (based on Global Positioning System readings) and B (based on inclinometer).<sup>a</sup>

Statistic	Original distances	Method A	Method B
Estimated $f(0)$	0.0019 $\pm$ 0.000156	0.0019 $\pm$ 0.000152	0.0017 $\pm$ 0.000125
No. of model parameters	1.158 $\pm$ 0.42	1.161 $\pm$ 0.43	1.293 $\pm$ 0.50

<sup>a</sup> True model has 1 parameter, with  $f(0)$  being 0.0019.



Bear with cub of the year running.

different sets of people collected declination angles and altitudes, these would show much greater observer variability than if method A was used. The pattern of the error in the actual survey, considering those distances for which we had also a declination angle and altitude, presents even stronger overestimation for distances of <400 m (J. Aars et al., Norwegian Polar Institute, unpublished data). Given that the errors at close distances are the most influential ones, it is believed that the effect of such errors, had method B been used, could be even worse.

It was interesting that the errors of method B lead to the need for, on average, a model with a higher number of parameters, a fact previously noted in Marques (2004).

Note that it was difficult for the helicopter pilot to fly exactly over the line when passing over the hut and the first person. Therefore, the distance measured by T. A. Marques and M. Andersen was the distance from the second person to the “bear,” and not the distance from the line to the bear. This is justified because, in the actual survey, the transect line is the helicopter flight path, so the component of the error associated with not being able to fly exactly over the preestablished line is absent.

The situations in which GPS might be used as described here are restricted to helicopter surveys of animals at low density, for which the original position is, in most cases, easy to identify. However, the increasing precision of portable GPS units means

that adaptations of the procedures to other similar situations may be useful. The use of laser rangefinders in terrestrial surveys is highly recommended, as well as any technology that reduces measurement error.

Error in horizontal distances derived from an inclinometer is the result of 2 sources of error: errors in altitude and in the inclination angle. These might both be additive, but the resulting error might not be so; additive errors in angle result in a skewed error distribution for distances because a positive error in angle generates greater upward bias in the distance error than the downward bias generated by a negative error of the same magnitude in the angle. However, since the altitude measurement was not error free, we could not disentangle these 2 effects. For aerial surveys in which individual GPS positions for each detection cannot be recorded, the use of aligned permanent marks on the helicopter or plane should be considered, especially if flight could be kept at constant height. For each detection the observer records the bin it falls in, according to which marks it passes between, and the subsequent analysis is of the resulting binned data. However, in helicopter surveys, it can be difficult to maintain level flight, and tilting of the craft creates bias in categorizing detections by bin, and, again, the errors tend to be biased towards larger distances.

This work shows that the use of an inclinometer for estimating angles from which, together with altitude estimates, distances can be estimated, can generate bias in density estimates. This illustrates the importance of using field procedures that yield distance estimates with low bias and high precision. Whenever possible, it is better to eliminate the problem of poor distance estimates in the field, by changing the survey protocol, rather than to rely on analysis methods such as those of Chen (1998) or Marques (2004).

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