SIZE BIAS IN LINE TRANSECT SAMPLING: A FIELD TEST

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SUMMARY

An important problem in line transect sampling is that objects or point clusters of objects of different sizes have different sighting probabilities. In a recent paper Drummer and McDonald (1987) develop a bivariate sighting function. Their function is dependent on perpendicular distance and object size. One important special case is an extension of the exponential power series sighting function first proposed by Pollock (1978). In this note empirical evidence is given for this model based on a field test of line transect sampling theory. Beer cans were used to simulate point clusters of objects with 1, 2, 4 and 8 cluster sizes.

Key words: Clustered populations; Line transect; Size biased sampling; Weighted distributions; Exponential power series distributions.

1. Introduction

An important problem in line transect sampling is that objects (or point clusters of objects) of different sizes have different sighting probabilities. This violates an assumption of the standard model (Burnham et al. 1980) and is an example of size biased sampling (Drummer and McDonald 1987).

In a recent paper Drummer and McDonald (1987) present a general model for size bias in line transect sampling. To illustrate, let us consider the exponential power series sighting function (Pollock 1978)

$$g(x) = \exp\left[-(x/\lambda)^{p}\right] \tag{1}$$

where x is the perpendicular distance of the object from the transect line, λ is a scale parameter and p is a shape parameter. If $p = 1$, we have an exponential sighting function while if $p = 2$, we have a half normal sighting function and as $p \rightarrow \infty$ we approach a uniform sighting function. By definition g(x) is the probability of sighting an object given it is perpendicular distance x from the transect line (Burnham et al. 1980).

A generalized sighting function dependent on both perpendicular distance (x) and size (y) would be

$$g(x,y) = \exp\left[-(x/\lambda(y))^{p(y)}\right] \tag{2}$$

where the scale parameter λ and the shape parameter p now depend on y. Drummer and McDonald (1987) and unpublished work by Pollock (Institute of Statistics, Mimeo Series No. 1669, North Carolina State University, Raleigh, North Carolina, 1985) suggest the model where $p(y) = p$, the shape parameter does not depend on y, and the scale parameter has the simple increasing relationship

$$\lambda(y) = \lambda y^{\alpha}. \tag{3}$$

Note that α is a parameter greater than 0 which defines the degree of size bias. If α equals 0 then $\lambda(y) = \lambda$ and there is no size bias.

In this paper we present empirical evidence (based on a field test carried out by Otto) supporting this model.

2. Results

2.1 The Field Test

In 1982, Otto carried out a test of the line transect method in a field near Raleigh, North Carolina. Two fixed transects of length 200 m and 160 m were used. Groups of brown painted beer cans with group sizes 1, 2, 4 and 8 were used to simulate objects of different sizes. The objects were placed randomly about each transect line to a distance of 20 meters. Nine observers walked along each transect line and told Otto which objects they saw. From this Otto was able to record the exact perpendicular distance and group size for each object seen by each observer. The observers never walked off the transect line so that there was not the problem of seeing a second object because of walking to examine an object. As Otto had a map of every object it was possible to estimate the probability of sighting each object based on the nine observers. In Figure 1 the estimated probability of sighting is plotted against perpendicular distance for transect 1 for each group size separately.

2.2 The Exponential Power Sighting Function

The first analysis we carried out was to fit equation 2 to the data. We used the procedure NLIN in SAS (SAS 1982) to fit the exponential power sighting function to each group size separately. The estimates of λ and p are given in Table 1 together with their standard errors. In Figure 1 the estimated sighting functions are plotted. Notice that there is clear evidence that the scale parameter is a function of group size while the power parameter estimates suggest a constant value of p near 2. (The weighted average estimate of p is 2.20 with approximate standard error 0.40.)

For simplicity we decided to fix p = 2 and refit each group size function separately using NLIN. The results are given in Table 2. Notice that the scale parameter estimates are almost identical with those in Table 1. Finally we fitted the relationship (3)

$$\lambda(y) = \lambda y^{\alpha}$$

to our scale parameter estimates using NLIN and obtained $\hat{\lambda} = 5.03$ (SE = 0.30) and $\hat{\alpha} = 0.28$ (SE = 0.04). The predicted values of $\hat{\lambda}(y)$ are given in Table 2 and compare closely to the original estimates. Note that our estimate of $\hat{\alpha} = 0.28$ (SE = 0.04) shows clearly that there is size bias. (A large sample Z test of H_0 $\alpha = 0$ vs H_1 $\alpha > 0$ gives Z = 7 with p value of 0.0000.)

3. Discussion

In this note we show strong evidence of the size biased sampling described by Drummer and McDonald (1987) and we also show the utility of their bivariate sighting function

$$g(x, y) = \exp [-(x/\lambda y^{\alpha})^{P}].$$

In our case $\hat{\alpha} = 0.28$ (SE = 0.04) showing clear evidence of size bias.

We also tried fitting the same model to the transect 2 data but unfortunately there was clear evidence of violation of a key assumption of line transect sampling, namely that objects on the transect line are never missed (Figure 2). Burnham et al. (1980) also noted violation of this assumption in a field study conducted by Laake on states. We believe this assumption needs close scrutiny with real data if it is clearly violated with artificial data (see also Pollock and Kendall 1987).

In retrospect we wish we had not used a random distribution of objects in our field test. A distribution uniform within distance classes from the transect line would have been better (by chance we obtained some distance classes with no objects). This is why in the analyses here we did not use program TRANSECT (Burnham et al. 1980) but rather worked with the estimated probabilities of sighting each object based on the multiple observers.

ACKNOWLEDGEMENTS

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REFERENCES

Burnham, K. P., Anderson, D. R. and Laake, J. L. (1980). Estimation of density from line transect sampling of biological populations. Wildlife Monograph 72. The Wildlife Society, Washington, D.C.

Drummer, T. D. and McDonald, L. L. (1987). Size bias in line transect sampling. Biometrics 43, 13-21.

Pollock, K. H. (1978). A family of density estimators for line transect sampling. Biometrics 34, 475-478.

Pollock, K. H. and Kendall, W. L. (1987). Visibility bias in aerial surveys: a review of estimation procedures. Journal of Wildlife Management 51, 502-510.

SAS. (1982). NLIN a non linear regression procedure. SAS Users Guide: Statistics. 1982 Edition. SAS Institute Inc., Cary, North Carolina.

Table 1. Fitting the exponential power sighting function to the Otto Beer Can data Transect 1 given in Figure 1. Estimates and (standard errors) of the scale and shape parameters.

Group Size	Scale ($\hat{\lambda}$)	Shape ($\hat{p}$)
1	4.55 (0.44)	2.66 (1.10)
2	6.52 (0.72)	1.94 (0.62)
4	7.62 (0.95)	1.92 (0.70)
8	8.88 (0.54)	3.58 (1.26)

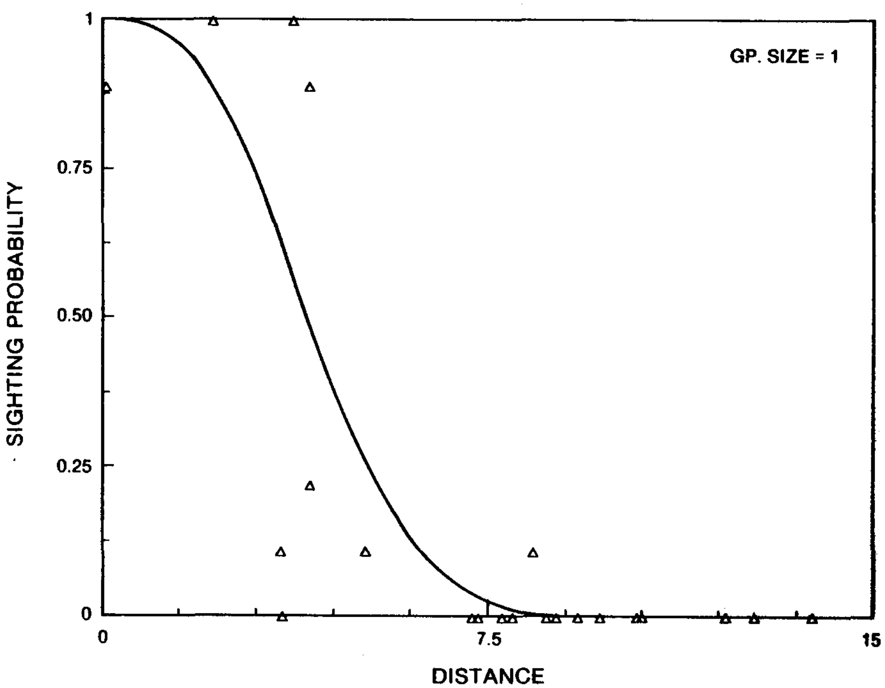
Table 2. Fitting the exponential power sighting function to the Otto Beer Can data Transect 1. Estimates of the scale parameter and (standard errors). Predicted values using $\hat{\lambda}(y) = \hat{\lambda} y^{\hat{\alpha}}$ are also presented. The shape parameter is fixed at p = 2.

Group Size	Scale ($\hat{\lambda}(y)$)	Predicted Scale
1	4.66 (0.45)	5.03
2	6.51 (0.69)	6.12
4	7.67 (0.83)	7.42
8	9.01 (0.75)	9.00

FIGURE CAPTIONS

Figure 1. Otto Beer Can data plot of empirical exponential power series sighting function versus perpendicular distance for each group size on Transect 1. The △'s give the proportion of observers who sighted each object.

Figure 2. Otto Beer Can data plot of empirical sighting probabilities versus perpendicular distance for group size 1 on Transect 2. The △'s give the proportion of observers who sighted each object.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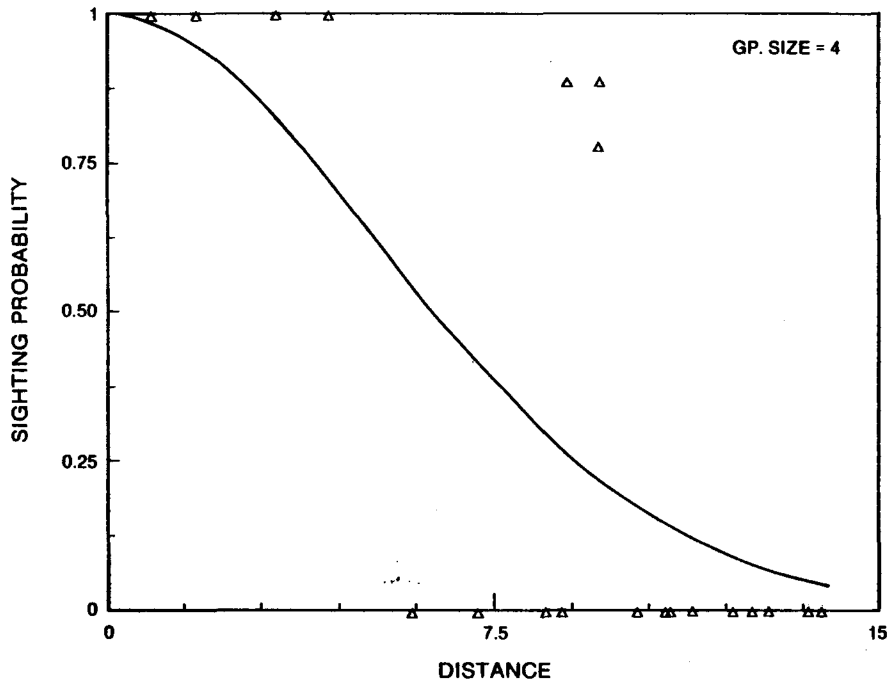
7.5
15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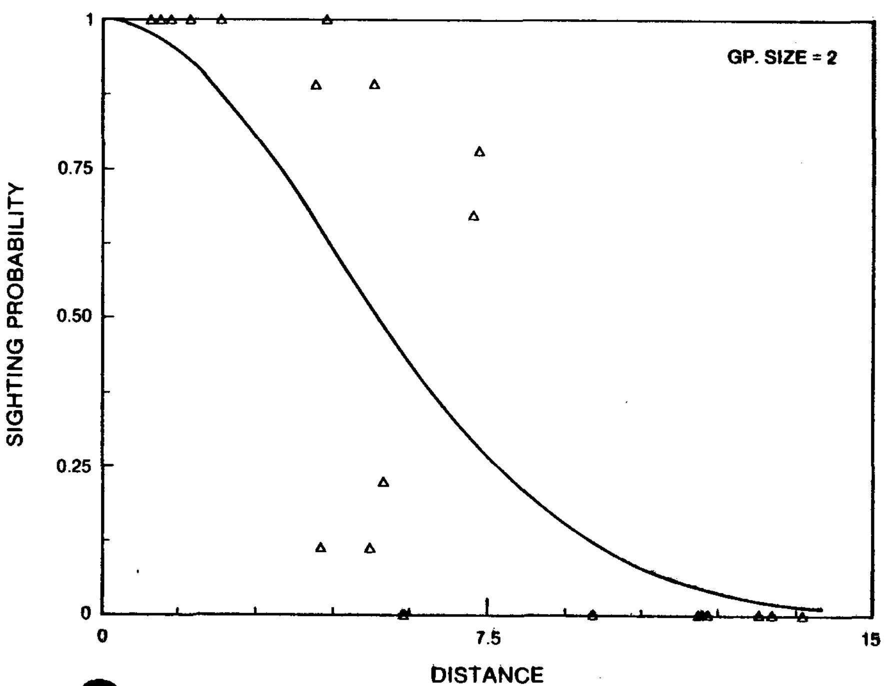
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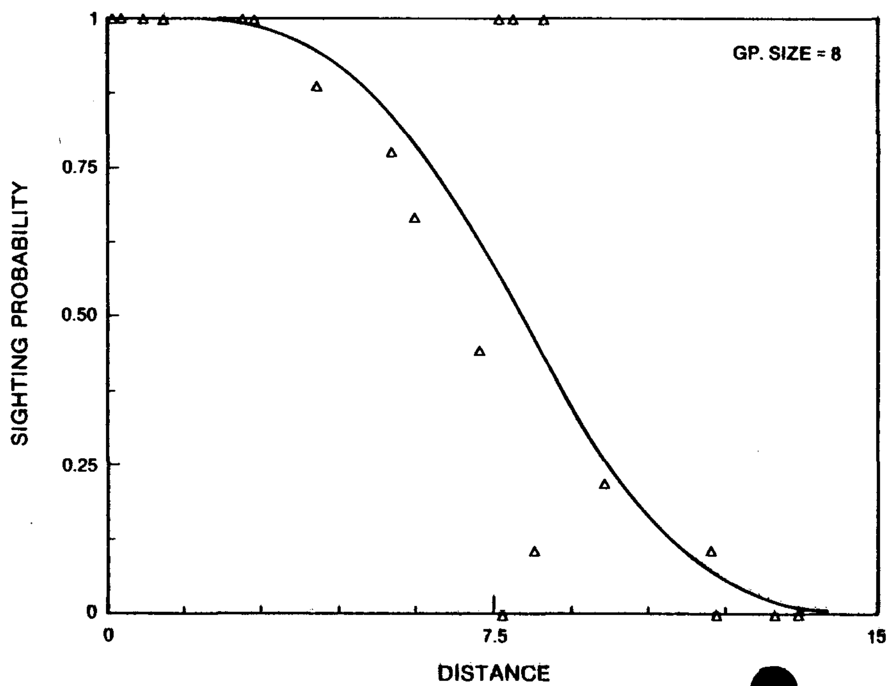
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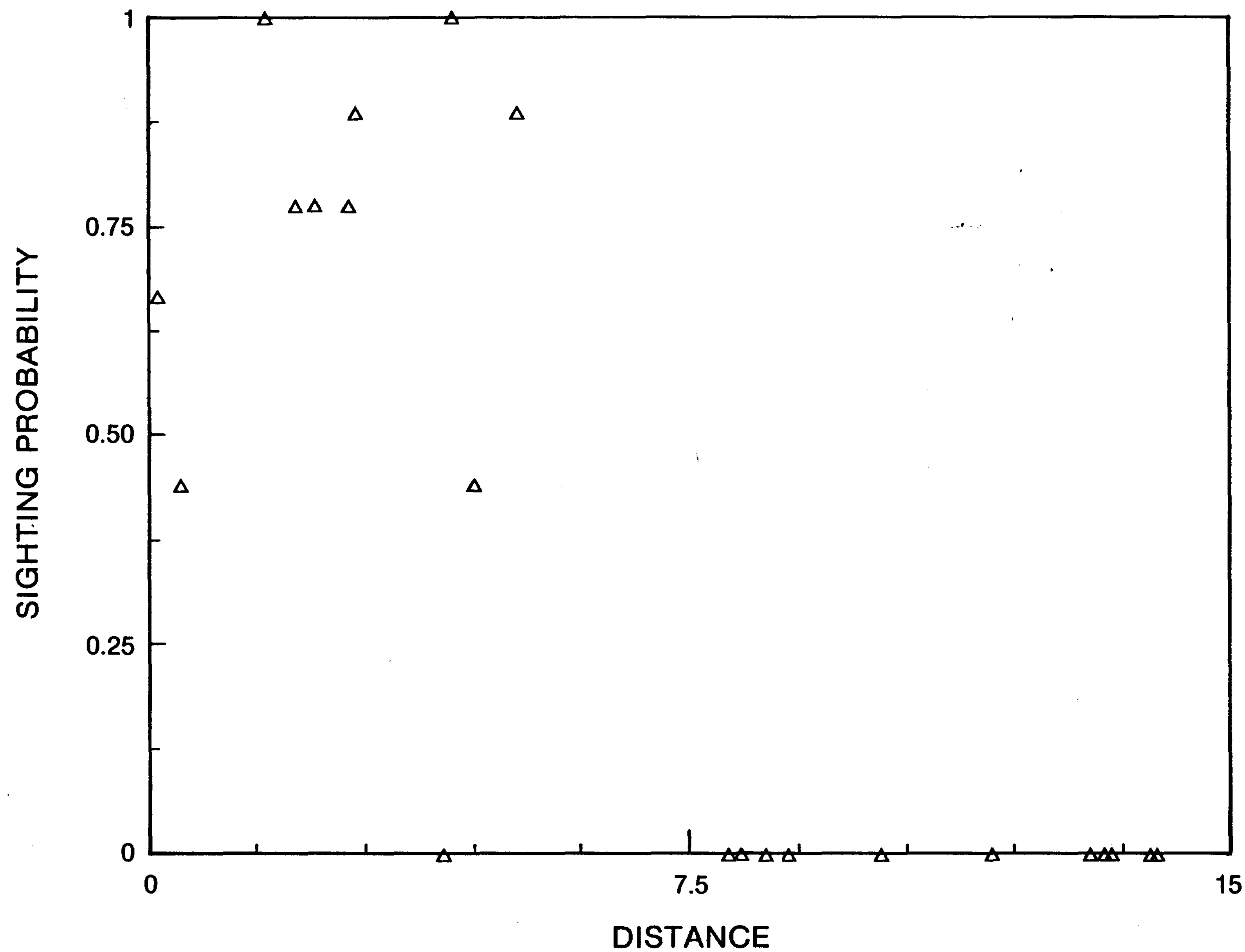
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