Bias in aerial censuses of Elephants in Etosha National Park, Namibia

M. LINDEQUE

Ministry of Environment and Tourism, Private Bag 13306, Windhoek

ABSTRACT

Received October 1992; accepted February 1993

Experimental counts of elephants in Etosha National Park were used to estimate the bias associated with low intensity counting methods developed for this species. Repeated counting of the same area showed that precise population estimates can be obtained from the method used, and that elephants react to survey aircraft by breaking up into smaller groups.Transect width in the range 1-4 km and altitude in the range 90-120 m could not be shown to affect population estimates within the ranges tested and applied in low-intensity elephant censuses. Photographic counts were less accurate than direct counts and could not be used to quantify counting bias.Counting bias proved to be difficult to estimate, but gross inaccuracies could not be detected and population estimates of elephants in Etosha are probably valid.

INTRODUCTION

Elephants are by virtue of their size, aggregation into groups and colour, regarded as the easiest terrestrial African mammal to count from aircraft in savanna regions.Only Eltringham (1972) attempted to determine the confidence that can be placed in aerial censuses of elephants. Caughley (1974), however, shows that results which appear satisfactory could be interpreted differently, and identified counting biases in Eltringham's (1972) data. Elephant censuses thus appear to be as subject to errors resulting from imprecise and from inaccurate counts, as censuses of other large mammals (Norton-Griffiths 1978).

Estimates of elephant population size have been derived for Etosha National Park (= Etosha) from aerial surveys since 1967, but logistical constraints have resulted in the use of widely varying counting techniques and census designs.Low-intensity censuses of elephants in Etosha were done since 1983 in addition to routine multi-species censuses based on narrow aerial transects and larger aircraft.The low-intensity elephant censuses yielded generally lower estimates of population size, which could be interpreted as the result of the less intensive census method used.The elephant population in Etosha occurs at a relatively low density and is unevenly distributed, with both factors typically resulting in a biased aerial census estimate (Norton-Griffiths 1978).

It was therefore necessary to estimate the bias in elephant counts in Etosha, at least for the recent censuses.Verification of the validity of population estimates from less-intensive counting methods was obtained from experimental counts of elephants, and this paper describes the approach followed.

METHODS

Basic elephant counting technique

A twin-seater fixed-wing aircraft (Piper Supercub) was used to obtain estimates of elephant numbers in Etosha in six censuses done from 1983-1985.The park was divided in two broad strata (shrubland and woodland), based on the structure and density of woody vegetation.Predetermined transects plotted on a 1:100 000 topographical map were used, but the starting points for transects were also determined from the time of flight since the end of previous transects.Transect widths used were 2 km and 4 km in woodland and shrubland respectively, double the widths used in previous censuses.Transect widths were demarcated by strut markers and streamers, as described by Pennycuick & Western (1972).Woodland and shrubland were flown over at an altitude of 90 m and 120 m respectively, conforming to previous censuses in Etosha and as used in East Africa (Norton-Griffiths 1978). Altitude was measured at the start of each transect, using a calibrated barometric aircraft altimeter and Pennycuick's (1973) shadowmeter.

Elephants not in line with the predetermined flight path, but within the limits of the transect, were counted by flying towards them and circling overhead for as long as necessary.Transect lines were interrupted when such a group was perpendicular to the transect line, and after the pilot had located a ground feature on which to re-align his flight path.This approach ensured that all groups sighted were counted accurately.Total group sizes, numbers of adult bulls, adult cows, and calves less than approximately two years old were recorded.The position of each group was plotted on a 1:100 000 map. Each family unit was photographed vertically at the designated transect altitude.

Transect design

Censuses in December 1983 and May and December 1984 were undertaken in approximately 100-700km^2 blocks demarcated by distinct ground features. Transects were flown across the long axis of a block, parallel to a conveniently straight side, usually more or less North-South (Design 1). In order to investigate census bias and a sample instead of a total census, the flight pattern was modified in subsequent censuses. Two sets of North-South transects were flown throughout the park in three elephant censuses in 1985 (Design 2).

Experimental counting

Design 3: As an estimate of precision, six arbitrary census blocks totalling 2 600 km^2 were counted twice in succession in the woodland stratum at a time when most trees had produced new leaves, and represented the worst conditions for visibility during the year in Etosha. The basic counting technique was followed with transects arranged as in Design 1. Repeated counts were compared with the Wilcoxon Signed Rank test (Zar 1984).

Design 4: A series of experimental transects of variable width and altitude were used in the August 1985 elephant censuses to determine the effect of these variables on apparent elephant density. The approach followed a model describing some major sources of variance in an aerial census (Caughley 1974; Caughley *et al.* 1976; Bayliss & Giles 1985). A woodland area with a relatively high density of elephants was chosen, and six treatment combinations of strip width (1 km, 2 km, 4 km) and altitude (90 m, 120 m) were randomly allocated to a series of North-South transects covering the whole area. The number of elephants counted was expressed as a density (Y=N/km^2). Areas of transects were calculated using designated strip width and lengths measured from a 1:100 000 map. Partial regressions of apparent density (Y) on strip width (X_1) and altitude (X_2) were calculated, using a polynomial multivariate regression method following Caughley (1974) and Steel & Torrie (1980).

Mark-resighting

A total of 30 elephants were marked with radio-collars and temporary painted numbers in 1984 and 1985, as part of a study of elephant movements in Etosha. Resightings of marked elephants during aerial censuses were used to roughly estimate census bias.

Photographic and direct counts

Elephants were counted from transparencies taken of family units during aerial censuses for photogrammetrical age estimation, and photographic counts were compared to direct counts of individual groups of elephants in the woodland stratum of the August 1985 census. Direct counts were made from the centre of the counting strip and at close range while circling over groups. As small calves are the most likely class to be counted inaccurately, the number of calves younger than approximately one year was used as an indication of accuracy.

RESULTS

Precision of census estimates

Table 1 presents estimates of precision in counting elephants in Etosha using the basic counting technique described in Design 3. The number of groups varied significantly between the first and second counts of census blocks, with more groups recorded in second than in first counts (Wilcoxon Signed Rank $T_- < T_{0.01(2),6}$). The total number of elephants in each block remained similar ($T_- > T_{0.01(2),6}$), indicating that disturbance by the aircraft caused herds to split into smaller groups.

TABLE 1: Mean (± Standard Error) percentage change in the number of groups of elephants and the number of individuals in first and second counts in six census blocks in Etosha National Park.

Number of groups in: First count	Second count	Time lapse between counts (min)	% change
12	20	30	+ 66.7
7	9	25	+ 28.6
17	22	45	+ 29.4
9	12	60	+ 33.3
2	2	15	0
5	6	20	+ 20.0
S: $T_- = 1 < T_{0.01(2),6}$*		x (±SE)	29.7 (±8.9)

Number of elephants in: First count	Second count	Time lapse between counts (min)	% change
139	145	30	+ 4.1
89	94	25	+ 5.6
121	118	45	- 2.5
93	90	60	+ 3.3
17	17	15	0
9	9	20	0
NS: $T_- = 7 > T_{0.01(2),6}$**		x (±SE)	1.8 (±1.3)

* Significant (Wilcoxon Signed Rank test)
** Not Significant (Wilcoxon Signed Rank test)

Accuracy of census estimates

The analysis of variance in apparent elephant density due to the individual and combined effects of changes in transect width and altitude is presented in Table 2. Elephant density was not significantly related to changes in both altitude or transect width, within the limits of those variables tested and thesub-optimal visibility in woodland.

Elephants marked during July 1984 and July 1985 were resighted in later censuses (Table 3). All those marked in July 1984 were present in the park and resighted in September 1984 and still showed the conspicuous painted numbers on their backs. By December 1984, most painted numbers were no longer conspicuous, but this is also the time when herds leave the park (Lindeque &

Lindeque 1991), which may account for the one herd missed.If only those censuses are used where marked elephants could definitely be recognized and were likely to have been in the census area, namely September 1984 and August 1985, the fractions not resighted were 0% and 11.5% respectively.

TABLE 2: Summary of analysis of variance in apparent elephant density (Y) in an experimental census of elephants in a 788km² section of Etosha National Park, using 15 transects with random combinations of altitude and transect width.

Source of variance	SS	df	MS	F
Main effect*:				
Transect width X_1	0.382	1	0.382	2.913 NS **
Altitude X_2	0.012	1	0.012	0.092 NS
Interaction:				
$Y/X_1;X_2$	0.370	1	0.370	2.822 NS
$Y/X_2;X_1$	0.001	1	0.001	0.001 NS
Residual	1.572	12	0.131	
Total	1.953	14		

* Random combinations of 1000m, 2000m and 4000m transect widths (X_1) with randomly allocated altitudes of 90m or 120m (X_2)
** Not Significant, $F < p$ 0.05

TABLE 3: Radio-collared elephants resighted during censuses of elephants in Etosha National Park.

Resightings in Census					
Marked:	July 1984:	Sept 1984	Dec 1984	May 1985	Aug 1985
Family unit members	12	12	11; 1M/A	12	10; 2M/A
Bulls	1	1	1	1 A	1 A
Marked:	July 1985:				
Family unit members	3	-	-	-	2; 1A
Bulls	14	-	-	-	11;2A;1M
no. (%) present		13 (100)	13(92.3)	12(92.3)	26 (86.7)
no. (%) seen of those present		13 (100)	12(91.7)	12 (100)	23 (88.5)
no. (% of total) known to be absent		-	-	1 (7.7)	4 (13.3)
no. (%) possibly absent or missed		-	1 (8.3)	-	3 (11.5)

M: missed
A : absent from Etosha

An attempt to count elephants from transparencies taken during censuses in Etosha resulted in lower counts when compared to direct observations. In the woodland stratum of the August 1985 census, 95 calves younger than approximately one year were counted directly, but only 85 could be counted from vertical aerial photographs. In the same census, only 71 calves were counted from the centre of the counting strip as compared to 95 counted at close range.

DISCUSSION

Caughley (1974) used the difference in the number of groups of elephants in a series of counts of elephants in Eltringham (1972) to estimate the true population size using a binomial model.The estimate thus obtained was larger than the total number of elephants counted in any one survey done by Eltringham (1972), which Caughley (1974) ascribed to counting bias.This may be unfounded if elephants elsewhere react to aircraft in a similar way as in Etosha (Table 1). Experimental designs including repeated counting to assess the eg. the efficiency of different procedures, aircraft and observers, may be compromised as a result of behavioural responses to disturbance. Estimates of elephant numbers can be precise, however, as long as methods are standardized, environmental conditions do not vary significantly between censuses, and all possible measures are taken to reduce the variation in possible sources of error from one census to the next.

The accuracy of estimates of population size is dependent on two types of errors. Some animals seen will not be counted accurately (type A), and some will never be seen at all (type B). Measuring and compensating for inaccuracies in counting individuals spotted are relatively easy compared to type B errors. The design of a census is usually aimed at minimizing the probability of not seeing a significant proportion of the population, usually by defining transect widths which ensures effective coverage of the area and adequate sightability of elephants. Transect widths were designed to ensure that most if not all groups were sighted (Lindeque & Lindeque 1997a), but actual counting has to be done at close range.Trial counts of herds on the outer edge of the counting strip were up to 25% higher than the real number recorded at close range (pers. obs.). Small calves are underestimated when counted from far away, but the number of adults is overestimated, the same type of error as in the classification of elephants into age groups from the ground at long range (pers. obs.).

Counting animals from photographs taken during an aerial census has been used successfully to counteract type A errors (Sinclair1973; Watson *et al.* 1969; Norton-Griffiths 1973, 1974, 1978). This technique appears to be most useful when counting large aggregations of species like wildebeest or buffalo. Photographs nevertheless introduce a new set of biases different from observer bias. Elephant calves were less easily seen on photographs than counting at close range. Circling over each group and observing its members from all angles ensured that groups were counted accurately, unlike the single view of a group captured on a photograph.

Various methods have been proposed to estimate the other cause of inaccurate estimates, namely the proportion of the population not seen and thus not counted. An analysis of the effect of major census variables did not reveal that estimates of elephant density were biased due to variation in altitude and transect width within the range tested (Table 2). Should such bias have been detected the model proposed by Caughley (1974) would have allowed the correction of population estimates to compensate for the fraction not recorded due to variation in the parameters investigated.

The number of known individuals in an area or population has been used to estimate bias in aerial surveys (Rice & Harder 1977; Gasaway *et al.* 1985; Packard *et al.* 1985; Crete *et al.* 1986).This is done by radio-telemetry or the use of conspicuously marked individuals.The proportion of known individuals to unknown ones is, however, an important consideration, and can be determined for specific sampling intensities following the Peterson estimation procedures, as described by Rice & Harder (1977).Where marked or known animals are present, the proportion of those seen during a total count may therefore be used to estimate bias in counting.One proviso is that marked individuals should not be more visible than unmarked ones, which may complicate the use of this method, as also in this study due to method of marking elephants.Conspicuous numbers painted on the backs of elephants might have rendered groups containing a marked individual more visible.The data presented here may serve only as an indication of the efficiency of the census in recording a number of known individuals, and not to estimate population size using mark-resighting theory.

Other methods based on double counts, binomial and parabolic estimates, have been used to estimate the number of animals missed or counting bias and thus to correct census results (Caughley 1974; Caughley & Goddard 1972; Magnusson *et al.* 1978). Routledge (1981) and Pollock & Kendall (1987) regard these methods as flawed by invalid assumptions. All methods using mark-resighting or replicate counts are fraught with technical problems, and may be more useful with stationary objects or larger samples. The utility of these methods lies in the ability to detect gross inaccuracy but does not extend to the calculation of the number of individuals missed. It is also possible that estimations of bias are more effective the greater the variance is between surveys or within a multiple sampling method.

Estimations of population size of elephants and other large mammals in Etosha since 1973 were derived from total count procedures using narrow transects (1-2 km), a helicopter and 4-6 seater fixed-wing aircraft, and done over a 4-6 week period. These censuses were expensive (approx. N\$10.50/km^2 at 1992 rates) and could not be done frequently enough to provide adequate estimates of population trend. The method used to count elephants in this study could not be shown to be grossly inaccurate compared to previous and more intensive methods used in Etosha. By using wider transects, and eventually a standard orientation of transect lines, flying time and costs could be reduced to 10 days and about N\$1.30/km^2 (1992 rate) without affecting the quality of estimates of population size. Low intensity counting techniques described in this paper could be useful in future when frequent counts of elephants are required, such as in a culling programme. Further reductions in the intensity of surveys were achieved by doing a sample count instead of a total count (Lindeque & Lindeque 1997b) but this reduced the precision of population estimates. Alternative approaches to counting elephants are nevertheless available to allow monitoring to continue despite a reduction in resources available for censusing.

ACKNOWLEDGEMENTS

The Director of Resource Management, Namibia granted permission to publish this paper.Several staff members contributed to census work, notably G. Noli as pilot and P. Lindeque who assisted with the analysis of census data.This paper includes work done under the supervision of the University of Stellenbosch.

REFERENCES

BAYLISS, P. & GILES, J. 1985. Factors affecting the visibility of kangaroos counted during aerial surveys. *J. Wildl. Mgmt.* 49: 686-692.

CAUGHLEY, G. 1974. Bias in aerial survey. *J. Wildl. Mgmt.* 38: 927-933.

CAUGHLEY, G. & GODDARD, J. 1972. Improving the estimates from inaccurate censuses. *J. Wildl. Mgmt.* 36: 135-140.

CAUGHLEY, G., SINCLAIR, R. & SCOTT-KEMMIS, D. 1976. Experiments in aerial survey. *J. Wildl. Mgmt.* 40: 290-300.

CRETE, M., RIVEST, L.P., JOLICOEUR, H., BRASSARD, J.M. & MESSIER, F. 1986. Predicting and correcting helicopter counts of moose with observations made from fixed-wing aircraft in southern Quebec. *J. appl. Ecol.* 23: 751-761.

ELTRINGHAM, S.K. 1972. A test of the counting of elephants from the air. *E. Afr. Wildl. J.* 10: 299-306.

GASAWAY, W.C., DUBOIS, S.D. & HARBO, S.J. 1985. Biases in aerial transect surveys for moose during May and June. *J. Wildl. Mgmt.* 49: 777-784.

LINDEQUE, M. & LINDEQUE, P.M.1991. Satellite tracking of elephants in northwestern Namibia. *Afr. J. Ecol.* 29: 196-206.

LINDEQUE, M. & LINDEQUE, P.M. 1997a. Using distance estimates in aerial censuses in northern Namibia. *Madoqua* 19(2): 65-73.

LINDEQUE, M. & LINDEQUE, P.M. 1997b. Aerial sample counts of large game in northern Namibia. *Madoqua* 19(2): 75-86.

MAGNUSSON, W.E., CAUGHLEY, G.J. & GRIGG, G.C. 1978. A double survey estimate of population size from incomplete counts. *J. Wildl. Mgmt.* 42: 174-176.

NORTON-GRIFFITHS, M. 1973. Counting the Serengeti migratory wildebeest using two-stage sampling. *E. Afr. Wildl. J.* 11:135-149.

NORTON-GRIFFITHS, M. 1974. Reducing counting bias in aerial censuses by photography. *E. Afr. Wildl. J.* 12:245-248.

NORTON-GRIFFITHS, M. 1978. Counting animals. Handbook 1. Nairobi: African Wildlife Leadership Foundation.

PACKARD, J.M., SUMMERS, R.C. & BARNES, L.B. 1985. Variation of visibility bias during aerial surveys of manatees. *J. Wildl. Mgmt.*49:347-351.

PENNYCUICK, C.J. 1973. The shadowmeter: a simple device for controlling an aircraft's height above the ground. *E. Afr. Wildl. J.* 11: 109-112.

PENNYCUICK, C.J. & WESTERN, D. 1972. An investigation of some sources of bias in aerial transect sampling of large mammal populations. *E. Afr. Wildl. J.* 10: 175-191.

POLLOCK, K.H. & KENDALL, W.C. 1987. Visibility bias in aerial surveys : a review of estimation procedures. *J. Wildl. Mgmt.* 51: 502-510.

RICE, W.R. & HARDER, J.D. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. *J. Wildl. Mgmt.* 41:197-206.

ROUTLEDGE, R.D. 1981.The unreliability of population estimates from repeated, incomplete aerial surveys. *J. Wildl. Mgmt.* 45: 997-1000.

SINCLAIR, A.R.E. 1973. Population increases of buffalo and wildebeest in the Serengeti. *E. Afr. Wildl. J.* 11: 93-107.

STEEL, R.G.D. & TORRIE, J.H. 1980. Principles and procedures of statistics. 2nd ed. Tokyo: McGraw-Hill Ltd.

WATSON, R.M., PARKER, I.S.C. & ALLAN, T. 1969. A census of elephant and other large mammals in the Mkomazi region of northern Tanzania and southern Kenya. *E. Afr. Wildl. J.* 7: 11-26.

ZAR, J.H. 1984. Biostatistical analysis. London: Prentice-Hall Int.