# Using distance estimates in aerial censuses in northern Namibia

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ABSTRACT

Transect widths were previously disregarded as a serious source of bias in aerial censuses of large game in northern Namibia. The cumulative number of sightings per species was recorded at increasing distance away from the aircraft in recent aerial censuses in our region. Effective transect widths, as the distance away from the observer over which sightings accrue approximately linearly, were generally about half of the intended transect widths. Unless effective transect widths are determined, the spacing of flight lines in total aerial coverage censuses could bias population estimates severely. Effective transect widths may, however, be used for each species in a given census area counted by a random transect sample method.

## INTRODUCTION

The visibility of an object is a function of its size and distance away from the observer (Norton-Griffiths 1978; Burnham & Anderson 1984; Burnham *et al.* 1985). Aerial censuses are usually designed to optimize the probability of counting all target individuals in a given area, although this design objective is seldom based on adequate data relevant to each census environment. The inability to detect all target animals over a specified transect width (counting strip width) is regarded as the most serious source of error and bias in aerial surveys (eg. Anderson & Posphala 1970; Caughley 1977; Norton-Griffiths 1978; Samuel & Pollock 1981; Burnham & Anderson 1984; Burnham *et al.* 1985). Transect widths used in aerial censuses in northern Namibia are, however, rarely based on any experimental work, and the question whether all animals occurring in a specified transect width are really detected, is seldom asked.

Previous aerial censuses in Namibia were based on census techniques developed in east Africa, with little or no effort spent to assess the suitability of techniques to local conditions. That transect widths were ignored as a serious source of bias was evident from the absence of any attempt to demarcate transect widths during census flights in the past (pers. obs., departmental census reports). The potential for undercounting or overcounting in such censuses can be considered severe. Population estimates derived from total area coverage aerial censuses, ie. a systematic coverage of an area with equally spaced flight lines, were, however, used without any correction factor or estimation of bias in management schemes for large game in Namibian parks.

Extensive experimental work has been done to reduce the bias in aerial surveys (Pennycuick & Western 1972; Caughley 1977; Norton-Griffiths 1978; Burnham & Anderson 1984; Burnham *et al.* 1985). Considerable experimentation is required to develop a sightability model or other bias-correcting technique to suit the Namibian censusing environment, as described in Caughley (1974); Caughley *et al.* (1976); Samuel & Pollock (1981); Gasaway *et al.* (1985); Bayliss & Giles (1985); Pollock & Kendall (1987); De Young *et al.* (1989); Johnson *et al.* (1989). While it may be possible to develop optimal census methods for each target species, the most urgent consideration at present is to optimize and standardize the multi-species aerial censuses used in northern Namibia.

A relatively easy and inexpensive method for detecting bias due to incorrect transect widths, is the analysis of the distribution of sightings over increasing distances away from the aircraft (Anderson & Posphala 1970; Burnham & Anderson 1984), as is commonly used in line-transect estimates of abundance (Burnham *et al.* 1980, 1985). The utility of this approach is outlined in this paper, regarding the detection of bias, determining effective transect widths and assessing individual performance of observers used in aerial counts of large game in northern Namibia.

## MATERIALS AND METHODS

Counts of elephants (*Loxodonta africana*) as the largest and most visible target species in censuses of large game in northern Namibia were used to demonstrate the effect of increasing distance on the distribution of sightings. Streamers were attached to aircraft wing struts to represent distances of 0.5 km, 1.0 km, 1.5 km and 2.0 km away from the aircraft at 100 m altitude, following Norton-Griffiths (1978). A further category was used, namely greater than 2.0 km classed as 2.5 km. Distances from the transect line to all elephants seen were thus estimated in a series of elephant censuses in Etosha National Park (Etosha) (Lindeque 1988). The park was divided into two broad vegetation strata, namely woodland and scrubland based on the density and height of woody plants.

Estimates of the distance away from transect lines were obtained for all species counted in the 1987 total coverage aerial census of Etosha. Streamers were used to indicate distance intervals of 0.5 km, 1.0 km and 2.0 km to aid distance estimation. A part of this census was done by helicopter and streamers could not be used. Observers were asked instead to estimate the distance between transect lines and animal sightings as less or more than half the designated transect width. All distance data presented are estimates, as it was not possible to measure any distance from the aircraft accurately. Sightings directly underneath the aircraft were included in the first interval. The number of sightings at eg. 1.0 km represent sightings from the previous interval, eg. > 0.5 km up to 1.0 km.

The distances away from transect lines were estimated in multi-species sample aerial censuses of Etosha, the Kaokoveld, Khaudom Game Reserve (Khaudom), eastern Bushmanland and approximately 1800 km$^2$ of commercial farmland near Grootfontein in 1990, as described above. The distribution of sightings over increasing distance was used to define effective strip widths per species in each censusing area, as the distance over which the cumulative number of sightings did not show an inflection. Curves were evaluated by eye.

Transect width is the term used for the demarcated distance on both sides of the aircraft in which counting is done. Half-transect widths thus refer to the counting strip width on one side only. Effective transect widths are defined as twice the distance away from the aircraft over which sightings increase approximately linearly.

## RESULTS

### Single-species censuses

Neither the number of elephants nor the number of groups of elephants sighted over increasing distance from the transect line during elephant censuses in Etosha declined within the intended half-transect widths of 1.0 km and 2.0 km in the woodland and scrubland strata respectively (Fig. 1). A single experienced observer was used in this series of censuses and it seems that elephants can be accurately counted in comparatively wide transects in Etosha.

### Multi-species censuses

During the 1987 multi-species aerial census of Etosha, most observers (including some of the most experienced and often-used participants in aerial censuses in Namibia) spotted significantly fewer groups in the further half of the transect width than in the nearer half (Fig. 2).

Elephant and Ostrich (*Struthio camelus*) were ranked most sightable while greater Kudu (*Tragelaphus strepsiceros*), and black rhino (*Diceros bicornis*) were ranked least sightable (Table 1). However, crude correction factors did not increase with decreasing sightability (Table 1).

Compared to Figure 1, the reduction in elephant sightings over the second half of the transect width (Table 1A) seems to indicate that observer bias was more severe during a multi-species, multiple observer census. The overall distribution of sightings in first and second halves of half-transect widths was similar in the helicopter and fixed-wing aircraft strata.

### Determination of effective transect widths

In Figures 3-8 inflections and asymptotes indicate a decline in the rate of additional sightings at a given distance in a series of multi-species censuses in northern Namibia. The most severe misjudgement of intended transect width occurred in the census in the Kaokoveld (Figure 5) where despite the open terrain few sightings occurred beyond 1000 m, or half the intended transect width. Effective transect widths for nearly all species in all five census areas were half of the intended transect widths (Table 2), thus indicating that population sizes derived from these censuses would have been underestimated unless a correction procedure was used (eg. Lindeque & Lindeque 1997).

## DISCUSSION

Estimates of the distance between aircraft and objects presented here cannot be used to provide additional data on animal density, in the sense of line-transect estimations of density (Burnham *et al.* 1985) or modified transect estimates (Caughley 1977; Collinson 1985). The

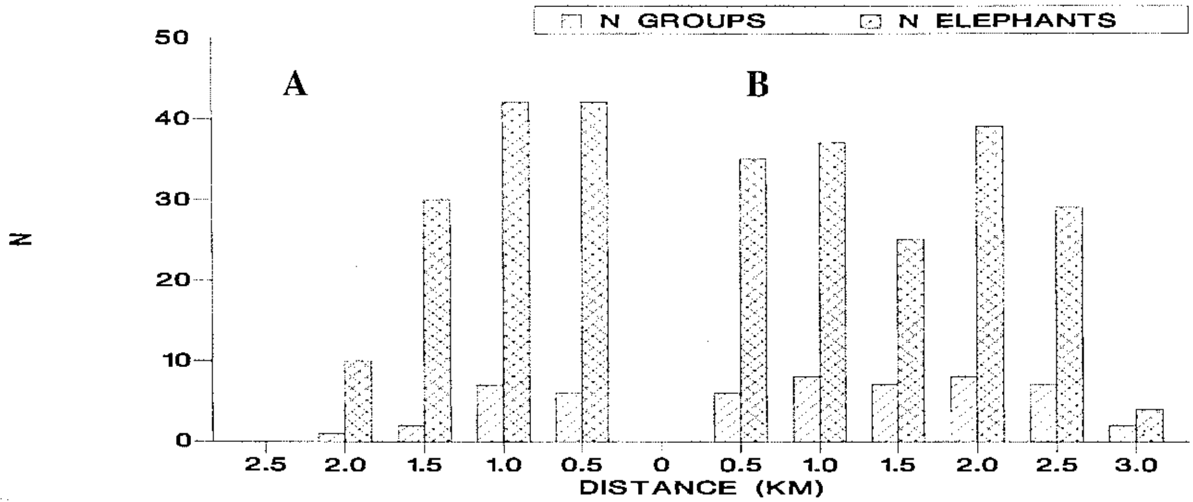


FIGURE 1: The number of groups and the number of elephants counted at increasing distance from the aircraft in the woodland (A) and shrubland (B) strata in Etosha National Park.

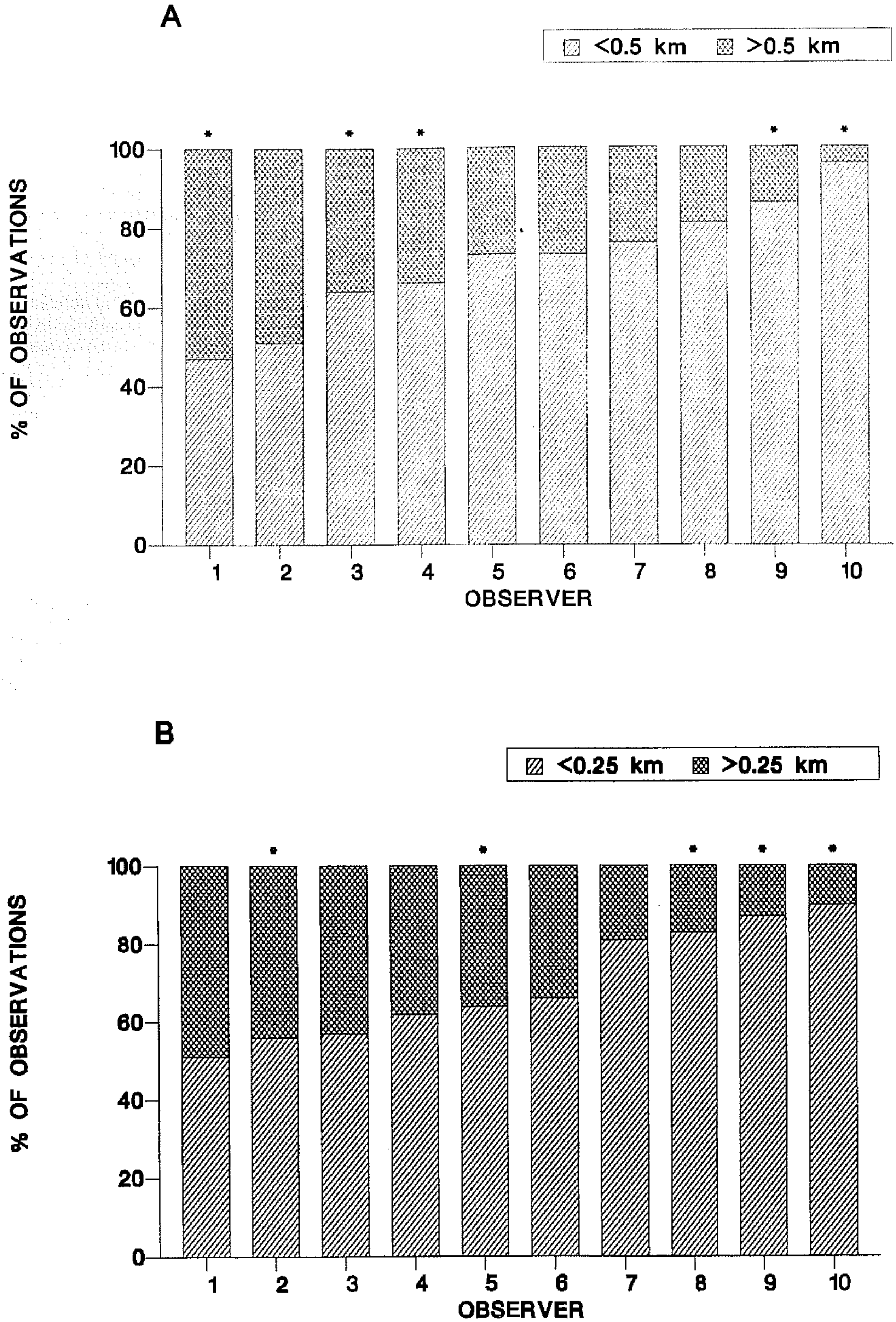


FIGURE 2: Schematic illustration of the differences in the number of groups of all species counted in the first and second halves of transect widths by ten observers in a fixed-wing aircraft (A) and ten observers in a helicopter (B) in the 1987 Etosha National Park census. (* denotes the most experienced census observers).

distance estimates presented here are regarded as too crude to allow any use other than an indication of suitable transect width in aerial censuses in Namibia. More accurate determination of the distances between observer and animals would allow either a correction of population estimates following Anderson & Posphala (1970) or entirely different treatment of data using more sophisticated methods (eg. Burnham *et al.* 1980).

TABLE 1: Number of groups and individuals ( ) of large game species counted in the first and second halves of the half-transect width by helicopter (A) and fixed-wing aircraft (B) in the 1987 aerial census of Etosha National Park. Species were subjectively ranked from most to least sightable.

**A**

| Species[1] | Distance away from helicopter | | | | | |
|---|---|---|---|---|---|---|
| | < 0.25 km A | | > 0.25km B | | $\frac{2A^2}{(A+B)}$ | |
| La | 61 | (500) | 37 | (332) | 1.25 | (1.20) |
| Sc | 182 | (512) | 161 | (401) | 1.06 | (1.12) |
| Ct | 84 | (1694) | 44 | (701) | 1.31 | (1.42) |
| Og | 270 | (1203) | 146 | (696) | 1.30 | (1.27) |
| Eb | 209 | (3001) | 106 | (989) | 1.33 | (1.50) |
| Ab | 37 | (307) | 20 | (150) | 1.30 | (1.34) |
| To | 22 | (163) | 18 | (83) | 1.10 | (1.33) |
| Am | 186 | (6208) | 34 | (847) | 1.69 | (1.76) |
| Gc | 207 | (605) | 161 | (345) | 1.13 | (1.27) |
| Ts | 97 | (486) | 62 | (373) | 1.23 | (1.13) |
| Db | 42 | (70) | 19 | (35) | 1.34 | (1.33) |
| Combined | 1397 | (14749) | 808 | (4952) | 1.27 | (1.50) |

**B**

| Species[1] | Distance away from fixed-wing aircraft | | | | | |
|---|---|---|---|---|---|---|
| | < 0.25 km A | | > 0.25km B | | $\frac{2A^2}{(A+B)}$ | |
| La | 36 | (396) | 38 | (448) | 0.97 | (0.94) |
| Sc | 102 | (302) | 77 | (263) | 1.69 | (1.07) |
| Ct | 15 | (303) | 17 | (426) | 0.94 | (0.83) |
| Og | 87 | (212) | 36 | (101) | 1.42 | (1.36) |
| Eb | 34 | (703) | 19 | (227) | 1.28 | (1.51) |
| Ab | 21 | (87) | 3 | (24) | 1.75 | (1.57) |
| To | 3 | (26) | 1 | (6) | 1.50 | (1.63) |
| Am | 76 | (1498) | 14 | (330) | 1.69 | (1.64) |
| Gc | 33 | (79) | 30 | (81) | 1.05 | (0.99) |
| Ts | 17 | (79) | 12 | (58) | 1.17 | (1.15) |
| Db | 20 | (30) | 7 | (14) | 1.48 | (1.40) |
| Combined | 444 | (3715) | 254 | (1978) | 1.27 | (1.31) |

[1] La = elephant (*Loxodonta africana*) Sc = ostrich (*Struthio camelus*), Ct= blue wildebeest (*Connochaetes taurinus*), Og= gemsbok (*Oryx gazella*), Eb= Burchell's zebra (*Equus burchelli*), Ab= red hartebeest (*Alcelaphus buselaphus*), To= eland (*Taurotragus oryx*), Am= springbok (*Antidorcas marsupialis*), Gc= giraffe (*Giraffa camelopardalis*), Ts= greater kudu (*Tragelaphus strepsiceros*), Db= black rhinoceros (*Diceros bicornis*).

[2] Crude correction factor to counter the apparent decrease in sightings over the second half of transect widths.

We have demonstrated that regardless of the census environment or technique followed, the rate of accumulation of sightings at increasing distance away from the observer, declines beyond a specific distance. This effect can be used to determine maximum transect widths which could be used to count a particular species or group of species in a given census area. More accurate determinations of the distance between objects and observers using accurate rangefinders are likely to reveal that effective transect widths should be even narrower than apparent from our data. From observations of observer behaviour during flights, it seems that fatigue and boredom lead to inadequate scanning of transect widths which require postural movements as well as differential eye focusing. These factors operate in addition to the expected decline in sightability over distance, which together result in biased population estimates.

We rarely have the resources to do single-species censuses in Namibia, and most censuses have to be optimized for a number of species. Optimal transect widths can be based on the overall distribution of sightings over distance, or the transect width indicated for the most important species among the target group. This constraint largely applies to total area coverage censuses, where the initial spacing of transects must be based on some knowledge of effective transect widths. If a standard transect width is chosen but not demarcated, some species may be undercounted, and others overcounted. The same group of animals recorded (but actually falling outside the transect width) on a transect would be seen by observers on the other side of the aircraft in the consecutive transect.

As long as the effective transect widths are determined for each species separately, the calculation of population estimates from random transect multi-species sample censuses is not affected, only the resulting sampling intensity. Transect widths are used in the calculation of population estimates from transect sample counts (Norton-Griffiths 1978) and the width used has a significant effect on population densities. There is no reason not to use individual transect widths for each species. There seems to be no better determination for locally effective strip widths available, other than those in Figures 3-8. We suggest that differential strip widths can be used to calculate population estimates from sample counts, where eg. giraffe (*Giraffa camelopardalis*) sightings in the Kaokoveld up to 600 m away from the aircraft are used, compared to elephant sightings up to 1000 m. The sampling intensity of such a sample census would thus be proportionately less for giraffe than elephants, as a smaller area was covered effectively. This approach would require an estimate of distance for every sighting in every census. The number of groups sighted in the relevant censuses were used throughout in this paper in favour of the number of individuals. With a large enough sample the latter could also be used, but could otherwise severely bias analyses of sightings over distance for species occurring at low density and/or with a clumped distribution.

Aerial censusing is the most important method for long-term monitoring of population trends in large game in

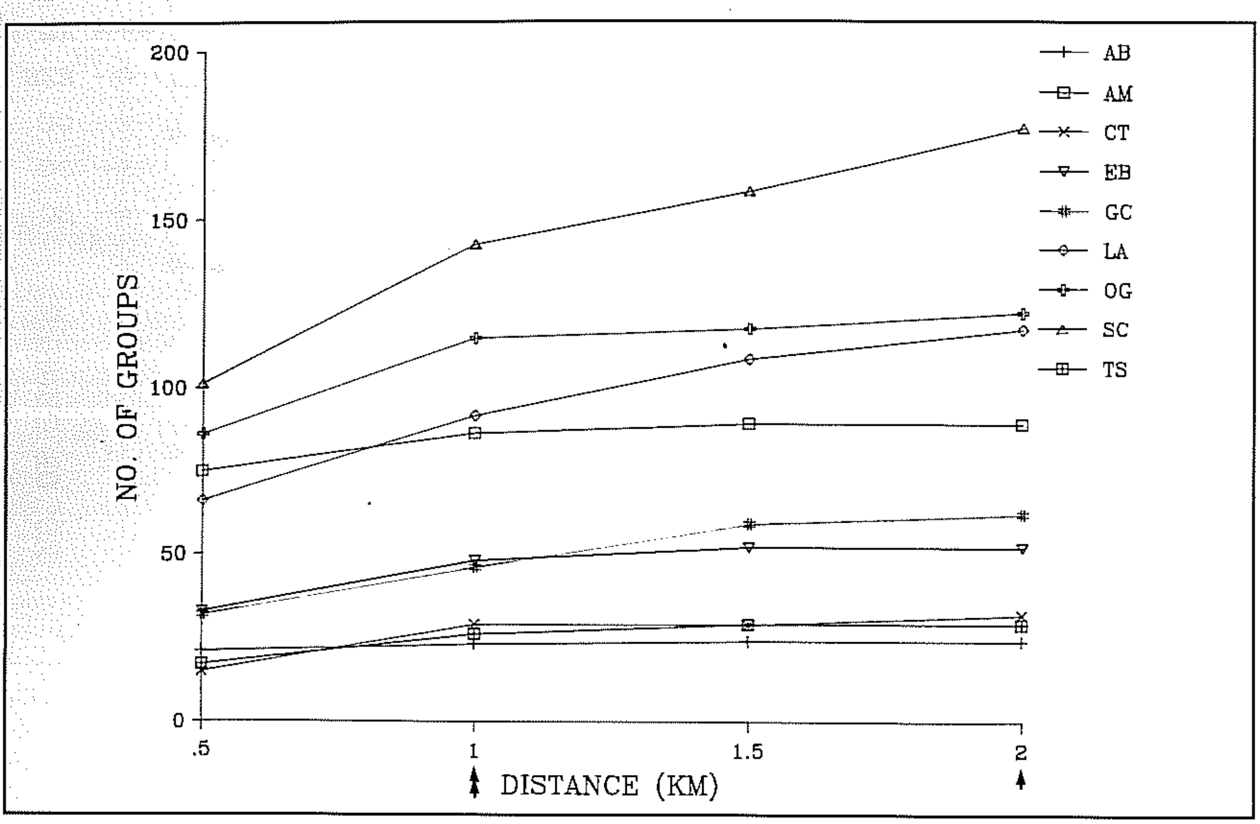


FIGURE 3: The cumulative distribution of sightings of groups of large game species at increasing distances away from transect lines in the September 1987 aerial census of Etosha National Park. (Arrow and double arrows denote intended aircraft half-transect width for the fixed-wing aircraft and helicopter respectively) (AB= red hartebeest, AM= springbok, CT= blue wildebeest, EB= Burchell's zebra, GC= giraffe, LA= elephant, OG= gemsbok, SC= ostrich, TS= kudu).

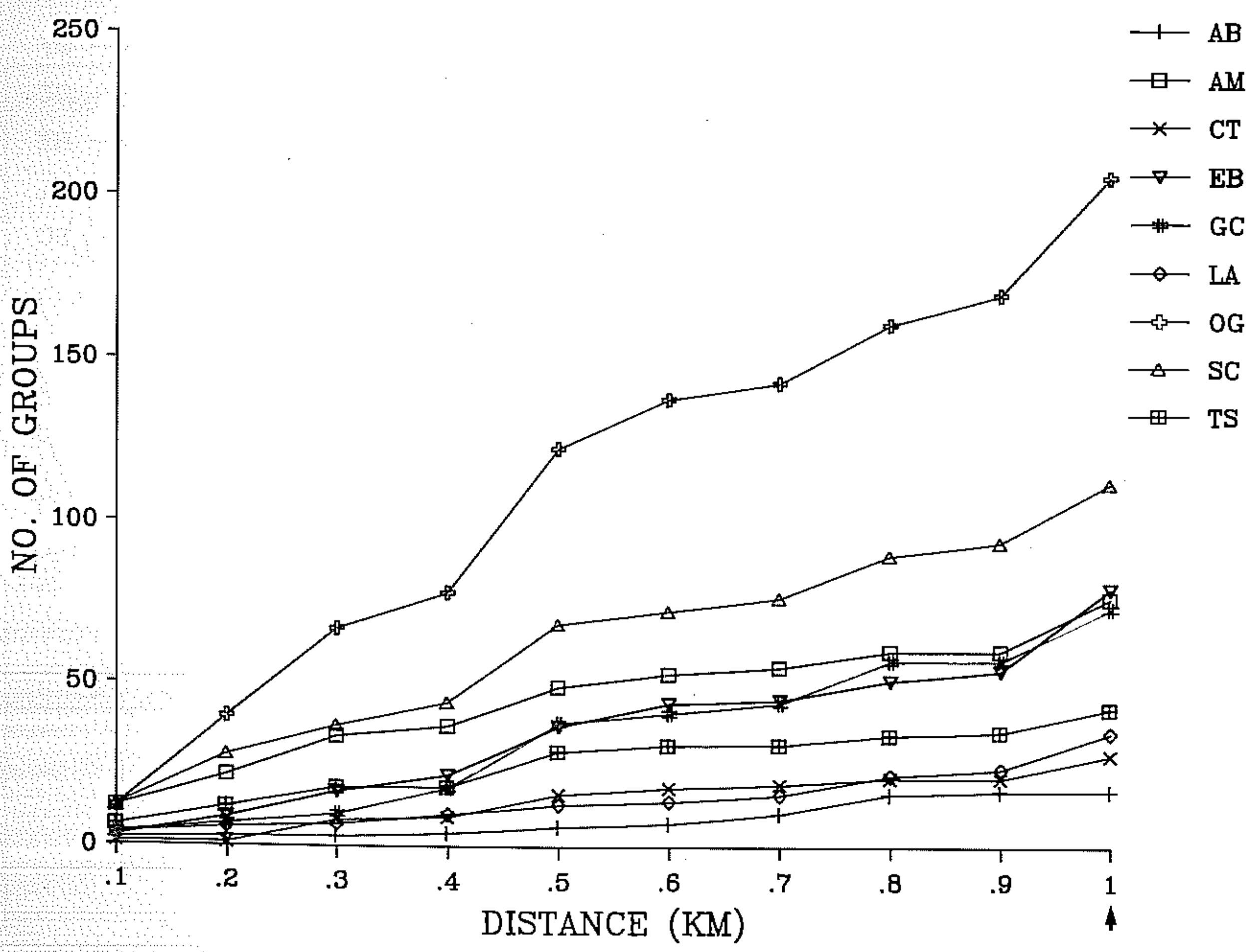


FIGURE 4: The cumulative distribution of sightings of groups of large game species at increasing distances away from transect lines in the August 1990 aerial census of Etosha National Park. (Arrow denotes intended half-transect width) (Species codes as in Figure 3).

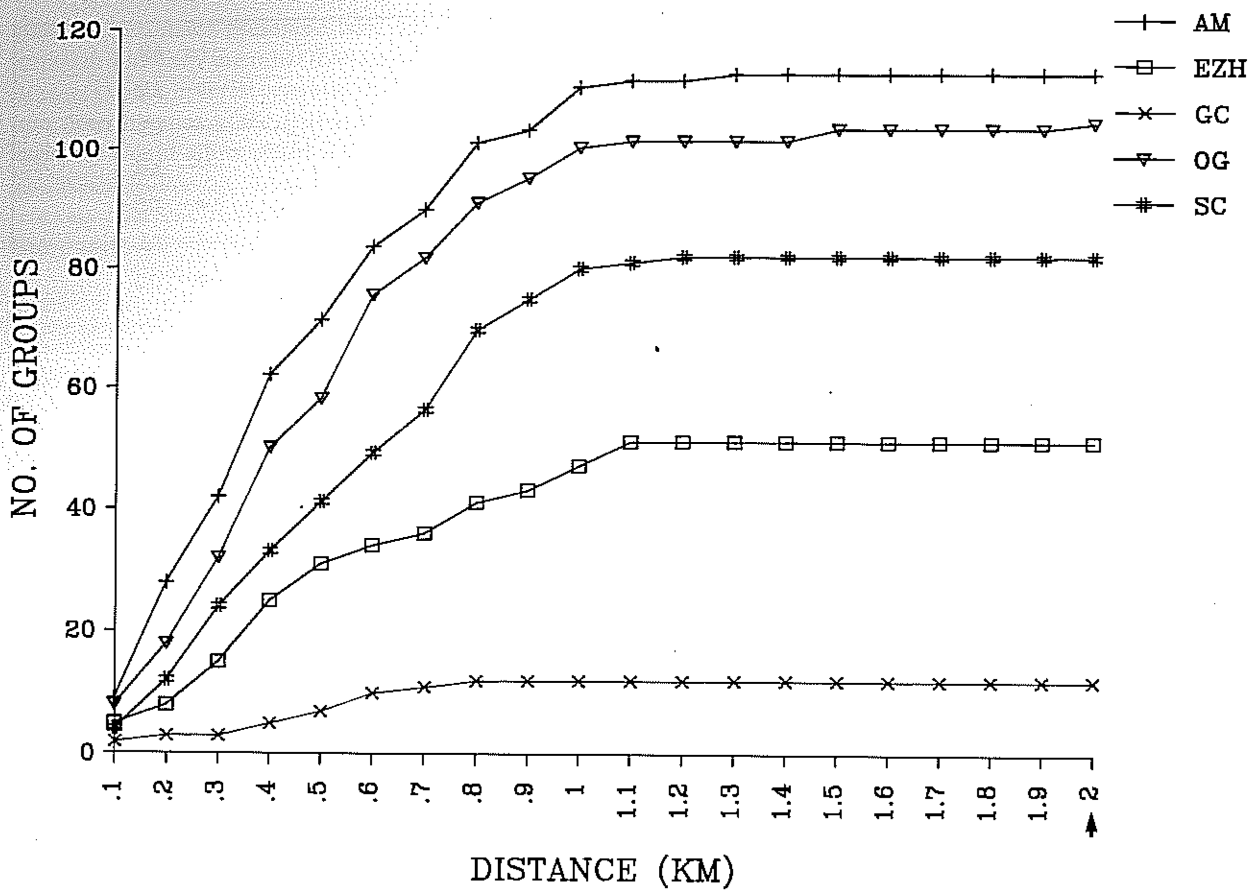


FIGURE 5: The cumulative distribution of sightings of groups of large game species at increasing distances away from transect lines in the May 1990 aerial census of the Kaokoveld (Skeleton Coast Park, Damaraland, western Kaokoland) (Arrow denotes intended half-transect width). (Species codes as in Figure 3, EZH= Hartmann's zebra).

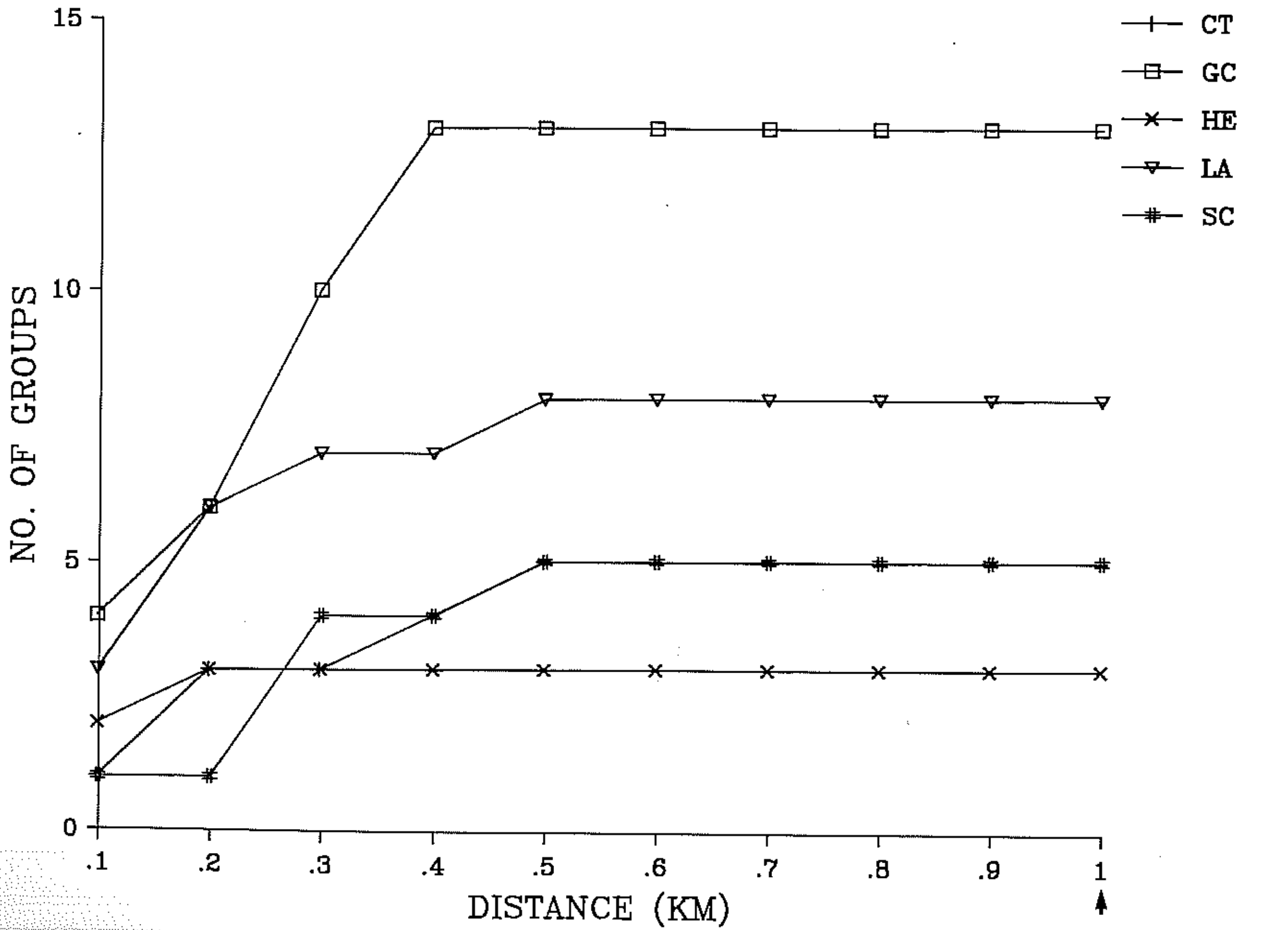


FIGURE 6: The cumulative distribution of sightings of groups of large game species at increasing distances away from transect lines in the October 1990 aerial census of the Khaudom Game Reserve (Arrow denotes intended half-transect width). (Species codes as in Figure 3, HE= roan antelope).

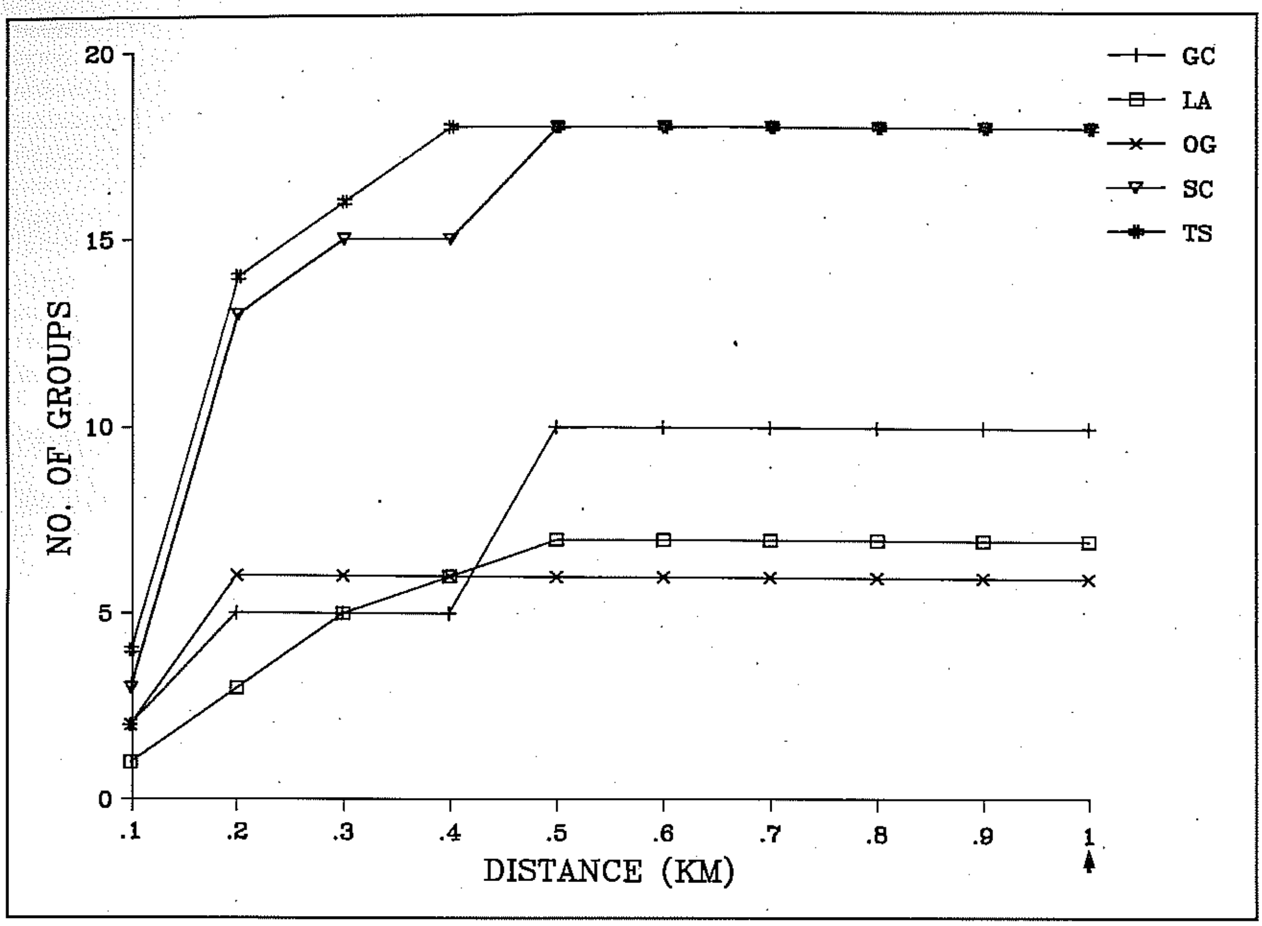


FIGURE 7: The cumulative distribution of sightings of groups of large game species at increasing distances away from transect lines in the October 1990 aerial census of eastern Bushmanland (Arrow denotes intended half-transect width). (Species codes as in Figure 3).

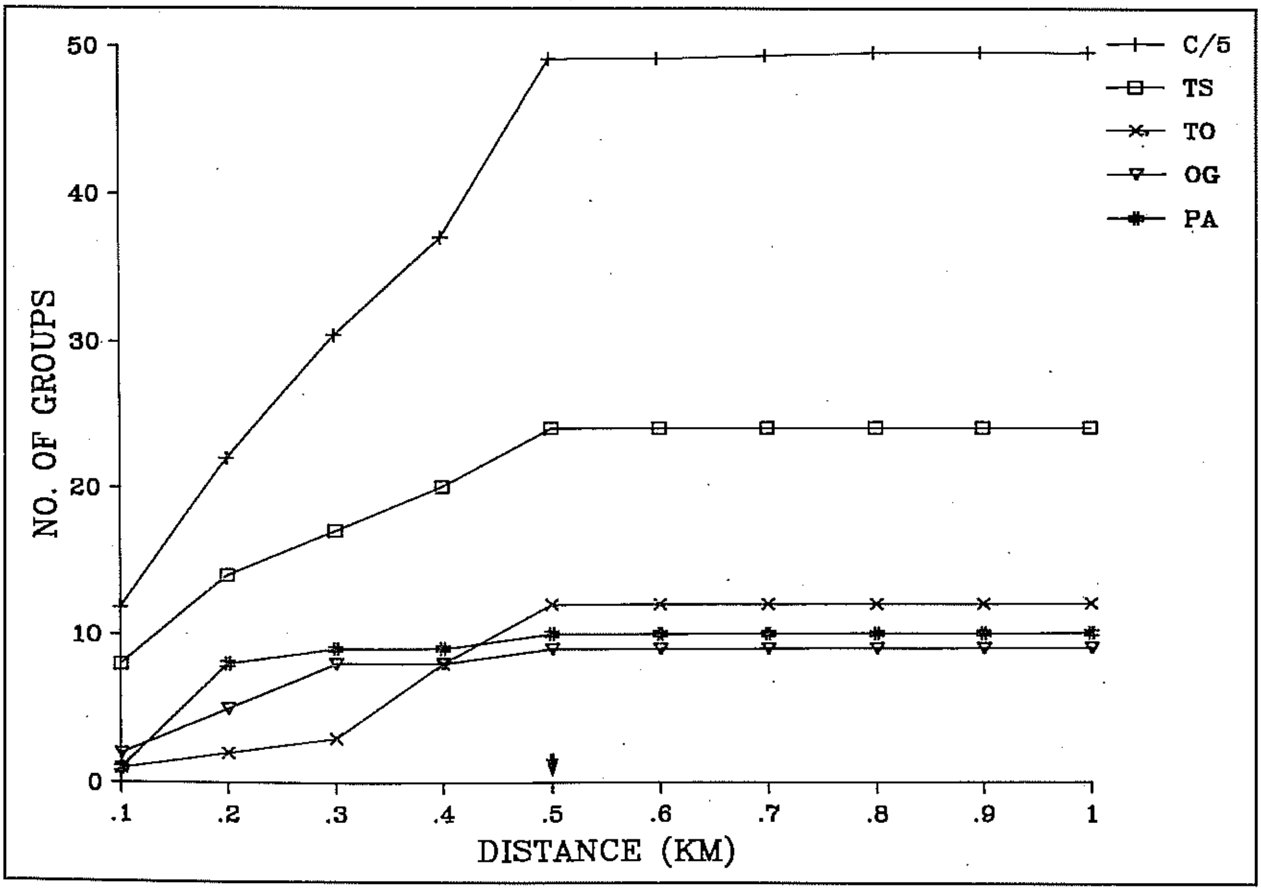


FIGURE 8: The cumulative distribution of sightings of groups of large game species at increasing distances away from transect lines in the November 1990 aerial census of approximately 1800 km² commercial farmland near Grootfontein (Arrow denotes intended half-transect width). (Species codes as in Figure 3, C= cattle, PA= warthog).

TABLE 2: Effective strip widths determined from the pattern of cumulative sightings over increasing distance from the aircraft for large game species counted in five census areas in northern Namibia.

| SPECIES[1] | APPROX. LINEAR INCREASE IN SIGHTING (0-) IN km | EFFECTIVE STRIP WIDTHS IN km |
|---|---|---|
| *ETOSHA* | | |
| La | 1 | 2 |
| Sc | 0.5 | 1 |
| Ct | 0.5 | 1 |
| Og | 0.5 | 1 |
| Eb | 0.5 | 1 |
| Ab | (1)[4] | (2)[4] |
| To[2] | (1-2)[4] | (1-2)[4] |
| Am | 0.5 | 1 |
| Gc | 0.5 | 1 |
| Ts | 0.5 | 1 |
| Db[2] | 0.5 | 1 |
| Amp[3,2] | (<0.5)[4] | (<0.5)[4] |
| Ezh[5,2] | 0.5 | 1 |
| *KAOKOVELD* | | |
| La[2] | 2 | 4 |
| Sc | 1 | 2 |
| Og | 1 | 2 |
| Ezh | 1.1 | 2.2 |
| Gc | 0.8 | 1.6 |
| Am | 1 | 2 |
| *KHAUDOM* | | |
| La | 0.5 | 1 |
| Sc | 0.5 | 1 |
| Ct | (0.3)[4] | 1 |
| Og[2] | 0.5 | 1 |
| He[6] | (0.2)[4] | 1 |
| Gc | 0.4 | 1 |
| *EASTERN BUSHMANLAND* | | |
| La | 0.5 | 1 |
| Sc | 0.5 | 1 |
| Og | 0.2 | 0.4 |
| Gc | 0.5 | 1 |
| Ts | 0.4 | 0.8 |
| *GROOTFONTEIN FARMS* | | |
| C | 0.5 | 1 |
| Og | 0.3 | 0.6 |
| To | 0.5 | 1 |
| Ts | 0.5 | 1 |
| Pa[7] | 0.2 | 0.4 |

[1] As in Table 1
[2] Not illustrated in Figures 3-8
[3] Black-faced impala (*Aepyceros melampus petersi*)
[4] Sample sizes insufficient
[5] Hartmann's zebra (*Equus zebra hartmannae*)
[6] Roan antelope (*Hippotragus equinus*)
[7] Warthog (*Phacochoerus aethiopicus*)

northern Namibia. Despite this, censuses in the different census areas are characterized by a general lack of standardization and continuity. Bias has largely been ignored and population trends described from the previous census record are questionable. Escalating costs of aerial censuses have made a further change of method inevitable. Random transect sample counts have recently been done in census areas previously counted by total area coverage methods (Lindeque & Lindeque 1997) and with new emphasis on game on private land and adjacent to parks, the opportunity exists to develop a standard census method based on relevant sightability data for each census area.

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