Article — Artikel

Helicopter-based censusing of domestic dogs in Gauteng Province, South Africa

B K Reilly[a*] and F van der Vyver[b]

ABSTRACT

Decision support in veterinary epidemiology often depends on density estimates of domestic animals. These estimates are usually based on ground surveys of various types. Ground surveys are difficult to undertake in the informal housing settlements that are frequently encountered in developing countries. In addition, they are time-consuming and expensive. In this study, field experience in enumerating wildlife from helicopters was used to count domestic animals in Gauteng Province, South Africa. Data for domestic dogs are analysed for precision and accuracy and the technique evaluated in terms of its value for decision support.

Key words: accuracy, census, counting, density estimation, dogs, epidemiology, Gauteng, helicopter, power, precision.

Reilly B K, Van der Vyver F **Helicopter-based censusing of domestic dogs in Gauteng Province, South Africa**. *Journal of the South African Veterinary Association* (2000) 71(3): 187–191 (En.). Department of Nature Conservation, Technikon Pretoria, Private Bag X680, Pretoria, 0001 South Africa.

INTRODUCTION

The problem of estimating densities of domestic animals, particularly in informal settlements, has been well-documented.[18,23,36,37] Gauteng offers a good example of a mosaic of informal settlements and 'First World' urban developments. It has also been demonstrated that domestic animals form a link in the chain of disease transmission to humans[12], domestic stock and wildlife[15]. The last and its epidemiology has resulted in a specific focus on dog surveys in Europe[32,36]. In this context it is essential that veterinary health departments have access to more accurate and precise data relating to densities of relevant domestic animals within these areas.

Several authors have experimented with different methods of determining densities of domestic animals, with varying success. The current door-to-door survey methods employed in Gauteng are perceived as inadequate and expensive in the light of shrinking budgets. It is clear that an indirect method may have cost benefits and efficiency exceeding those of current ground surveys. The interaction between the Directorates of Veterinary Services and Nature Conservation in the Gauteng Department of Agriculture, Conservation and Environment (DACE), has led to the potential harnessing of game-counting expertise in nature conservation to solve the problem of domestic animal censuses, particularly for dogs, for the veterinary epidemiologists in the province.

The use of game-counts, in particular aerial counts, as a tool in the management of large ungulates can be traced back to 1935[5]. The use of aircraft and particularly helicopters has grown steadily since the Second World War and is today almost universally applied in enumerating many species of wild ungulates, *e.g.* white-tailed deer, mule deer and elk in Michigan[1,3,25]. In Africa, the method has been applied to many species of indigenous ungulates, and results recorded by many authors: counts of giant eland, roan antelope, Defassa waterbuck, Bohor reedbuck and Bubal hartebeest in West Africa[35]; impala, topi, sitatunga, eland and waterbuck in Rwanda[28]. In east Africa several authors have documented use of the method[9,17,22]. In the South African context the subject has been well covered by various authors[4,8,11,13,16,29,30,34]. Fixed-wing-based counts have also been applied in surveys of domestic stock in Sudan[37].

These surveys provide baseline densities that when revisited have as a secondary function the monitoring of change in these populations over time. It is essential that precision and preferably error probabilities be calculated as the basis of measurement efficiency of any monitoring method. The underlying logic dictates that in monitoring, ignorance of Type I and Type II error probabilities wastes time and money. Finally, it has been established that aerial counts by and large are subject to undercounting bias and thus ground confirmation (truthing) of data is essential.

Although numerous publications have reported the accuracy of helicopter counts and the effect of various factors such as height and speed on accuracy[2,3,4,10,26,31], and other investigations have focused on observer bias, there is a singular lack of references on the precision and power of these applications[14,22,24,28]. In a review of statistical power achieved in 14 research domains, no mention was made of wildlife management or veterinary epidemiology[20]. The use of power analysis has been documented in South Africa[29,30].

THE PROBLEM

There are intrinsically 2 problems associated with counting animals. First, and most often broached, is the problem of accuracy, or the relationship between the result in hand and the actual number of animals on the ground. This aspect is important in once-off surveys and, in the case of epidemiology, important for planning, as the accuracy is used to estimate a density from the count result.

Secondly, the problem of precision is often ignored in the application of animal counts and in general reporting on precision in aerial counting is sparse. Unless counts, or indeed any monitoring action are replicated, an ultimate management decision is made with unknown within-technique variation that may lead to a decision based on a Type I or Type II error. Essentially, statistical power analysis allows the calculation of Type II error for a pre-selected Type I error rate.

The objective of most aerial counts is to show population change over time, normally from one year to the next. The variation (precision) if unmeasured may exceed the magnitude of population change to be measured and thus render

[a]Department of Nature Conservation, Technikon Pretoria, Private Bag X680, Pretoria, 0001 South Africa.

[b]Gauteng Department of Agriculture, Conservation and Environment, P.O. Box 8769, Johannesburg, 2000 South Africa.

*Author for correspondence.

Received: February 2000. Accepted: July 2000.

the resulting estimate valueless. At best, large ungulate counts are subject to a high degree of standardisation on the assumption that high precision will be achieved. The high cost of aerial operations obviously mitigates against replicating counts.

OBJECTIVE AND KEY QUESTIONS

The objective of this study was to conduct replicated helicopter counts of randomised sampled areas of the urban and peri-urban environments of Gauteng, enumerating all domestic livestock. These data were used to determine the accuracy and precision of the technique per species to provide support for veterinary epidemiological decision-making and planning in the province. Only the results for dogs are presented here.

The following key questions were addressed:

1. What precision was achieved for counts of dogs?
2. What statistical power, hence Type II error probability, was achieved under pre-selected Type I error probability for the technique?
3. What accuracy can be expected from this method?
4. What is the estimated density of dogs, counted with acceptable precision and power, in the strata counted?

METHODS

Field data collection

The helicopter total count technique has many detractors but, despite failure to ensure that underlying assumptions have been met, the requirement for skilled observers and problems with high observer fatigue, difficulty in standardisation and high costs, it possibly remains the technique of choice in southern Africa[6,8,22,24,33]. Helicopter counts provide a dataset in a shorter time for smaller areas and are less sensitive to the area diversity and population sizes than many other sampling methods. The visibility from the air is also better than from the ground in most environments, particularly heavily-populated areas.

In this study a 4-seat Bell Jet Ranger III helicopter was used for the surveys with an air crew of pilot, navigator and 2 counters. Counting marker bars were set to delineate a 330 m wide strip at a height of 53 m above ground level. Height was regulated using a radar altimeter and all counts were performed with the rear doors removed. All counts were performed during August 1999 and replicates were conducted 1 day apart at the same time of day. Speed was constant at 96 km/h. Navigation was accomplished by heading and counter-heading and tracked by the navigator on 1 km^2 grid overlay.

Data were recorded using hand-held tape recorders and later transcribed to data sheets using the grid numbers of the overlay. Counts included all animals seen. The species observed were dogs, cats, poultry, cattle, sheep, goats, horses, donkeys, pigs, rabbits, tortoises, and other birds.

In terms of sampling, the province was stratified into high-, medium- and low-density areas according to human density. Density areas were extracted from the DACE Geographical Information System with all urban areas considered as high-density, all blocks adjacent to urban areas as medium-density and all other blocks as low-density areas. Three 900-hectare blocks were randomly selected in medium-density areas and three 900-hectare blocks in high-density areas and triple-counted on successive days using the above method. Sample blocks were randomly selected in the southern half of the province so as to reduce helicopter ferry time. This provided a total survey area of 6 blocks. For ground confirmation a random 100-hectare sample of each of these blocks was surveyed using a door-to-door method within 2 weeks of the aerial surveys.

Statistical analysis

Precision

Precision of the counts is expressed as a coefficient of variation, *i.e.*:

$$\frac{s}{\bar{x}} \times (100),$$

where s is the standard deviation and $\bar{x}$ the mean of the number of replicates. These values are expressed as a percentage in the results.

A regression analysis of the mean population counted for each block versus the standard error of the mean for each block was incorporated into the analysis. If significant, this correlation indicates that consistent variation can be expected from this method, demonstrating statistical robustness.

Randomisation and variance estimation

The count replicate results showed order dependency in that the variance for 2 replicates was often smaller than that of the 3 replicates. These results are counter-intuitive and influence power values accordingly. In order to obviate this and obtain a true estimate of population variance, the replicates were randomised with replacement and bootstrapped (n = 4000) to improve the estimate of the variance for the power analysis.

Power

In order to determine the power to detect a change in the population size, the assumption was made that the sample variance in year 1 is equal to the population variance in year 2.

The logic of the power analysis is to determine what degree of population change (effect size) can be detected significantly from time t to time $t + 1$.

In the formulae presented below, s denotes the standard deviation of the pooled replicated counts in year 1, and $\bar{x}_1$ denotes the mean in year 1 and $\bar{x}_2$ in year 2. The number of replicates in year 1 is n_1 and in year 2 the number of replicates is n_2.

The null hypothesis is:

H_0: $\mu_1 = \mu_2$,

i.e. $\mu_1 - \mu_2 = 0$,

i.e. the population means in year 1 and year 2 are equal.

One of the alternative hypotheses is that the mean in year 1 is larger than the mean in year 2, *i.e.* there is a decrease in size:

H_a: $\mu_1 - \mu_2 > 0$.

If the null hypothesis is true, then

$$P\left(\frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} > t_{n_1+n_2-2;\alpha}\right) = \alpha,$$

i.e. $P(t > t_{n_1+n_2-2;\alpha}) = \alpha$, where

$$\frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = t,$$

and $t_{n_1+n_2-2;\alpha}$ is the critical value of the t-distribution with $n_1 + n_2 - 2$ degrees of freedom. Hence, the variable t is assumed to have a t-distribution with $n_1 + n_2 - 2$ degrees of freedom.

To determine the power of detecting a change of $\Delta\bar{x}_1$ where $\Delta < 1$, the following probability is calculated:

$$P\left(t - \frac{\bar{x}_1}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} > t_{n_1+n_2-2}\right),$$

$$i.e.\ P\left(t > \frac{\bar{x}_1 + t_{n_1+n_2-2;} \cdot s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}\right).$$

Similarly, to detect an increase in size from year 1 to year 2 the following is calculated:

$$P\left(t > \frac{{}^*\Delta\,\bar{x}_1 - t_{n_1+n_2-2;\alpha} \cdot s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}\right),$$

where ${}^*\Delta\bar{x}_1 > 1$.

The standard (central or location-fixed) t-distribution cannot be used in this case and the non-central (location free) t-distribution is used [27]. The term non-central is applied to distributions of t where the single normal variable (numerator in the t -ratio) no longer has a zero expectation. The non-central (location free) t-distribution is computed as follows:

For $\alpha = 0.05$, $1 - \beta = 0.95$,

$$y = -1 \frac{t_\phi}{\sqrt{2\,df}} \left(1 + \frac{(-t_\phi)}{2\,df}\right)^{-\frac{1}{2}},$$

where degrees of freedom = $n_1 + n_2 - 2$, and t_ϕ = $TINV(0.025, df)$; I = table value for y and df;

$$\Delta = -\left[-t_\phi - I\left(1 + \frac{(-t_\phi)}{2\,df}\right)^{\frac{1}{2}}\right] \text{(non-centrality}$$

parameter), and standardised difference =

$$\Delta . \left(\frac{1}{n_1} + \frac{1}{n_2}\right)^{\frac{1}{2}}.$$

Accuracy

Accuracy is expressed as the ratio between the aerial observations of a species and the confirmed number of dogs on the ground.

Density estimates

Finally, density estimates were computed from the number of survey blocks in high- or medium-density areas (from GIS) multiplied by a correction factor for undercount bias. The 95 % confidence limit was computed using the bootstrapped standard deviation calculated for the power analysis.

General

All data summaries, intermediate analyses and results summaries were executed using Microsoft Excel (Microsoft Corporation, Los Angeles) and statistical analyses were accomplished with SPSS version 8 (Chicago).

RESULTS

The results are presented in tabular form and discussed below.

DISCUSSION

Precision

It is essential to clarify the issue of statistical power and its value in remote monitoring and decision-making. The significance levels (α or Type I error) or the probability of rejecting a true null hypothesis are usually set as small as possible in scientific experimentation[20]. It follows that the smaller the value, the more rigorous the rejections of the null hypothesis will be, therefore the existence of the phenomenon in question is accepted. Small α values often lead to relatively small power values, although power values are also dependent on other factors such as the alternative hypothesis[7,20]. The Type II (β error) or the probability of failing to reject a false null hypothesis is related to power (β = 1-power), low power thus relating to large values of β[7].

Post hoc power analyses can answer 3 questions. Firstly, the number of replicates that would be needed to detect a difference (effect size) of the magnitude observed in the data with pre-selected α and β[20], *i.e.,* how many replicates would be needed to detect real change in the number of animals from one year to the next. Secondly, what is the smallest difference that can be detected for a given number of replicates, again with pre-selected values of α and β, and finally, what is the statistical power of the test procedure? In this case analyses centre on the last 2 questions, given the fixed sample size of 3 replicates.

It is often argued that count data are Poisson-distributed, as this type of distribution is important in describing random occurrences of objects in space where each object has the same probability of being encountered anywhere in that space. In this case, however, a plot of the bootstrapped means showed the data to be normally distributed.

The summary data for the 3 counts appear in Table 1. The totals for the 1st, 2nd and 3rd counts for all 6 blocks were subjected to a power analysis as discussed above. The coefficient of variation (CV) is presented in Table 2 and as a scaled measure of variation allows comparison with other counts and any further counts. In reality the CV can be considered the best minimum estimate of the techniques ability to show change in a population over time.

Any change larger than the CV can be considered to be real change and not an artefact of the within-technique variation. These results demonstrate that in the case of dogs the method has been successful.

In Table 2 the results from Table 1 appear together with the bootstrapped estimates of variance, in this case specifically standard deviations for replicates 2 and 3. In addition to the aforementioned, the standard error (SE) terms are also computed and quoted for further analyses. The coefficient of variation for dogs at 6.51 % is smaller than those generally demonstrated in wildlife applications. Herd composition counts of black-tailed deer showed high variance, and raised questions about the value of the data in decision-making. CVs ranging between 6 and 36 % for commonly managed large ungulate species on Loskop Dam Nature Reserve have been demonstrated[21,29]. Variations in replicated counts using helicopters ranging from 0.9 to 32.3 % have been demonstrated in Texas, while CVs ranging from 16 to 41 % have been reported in fixed-wing counts of moose[2,19]. Variability between 12.0 and 32.2 % was obtained in counts of blesbok at Rietvlei Nature Reserve[16].

A significant correlation exists between mean counts of dogs per block and the SE of those means (R = 0.877), indicating constant variance, hence robustness of technique.

Power

Table 3 shows the intermediate-step statistics for the calculation of power in the case of the data for dogs, while Table 4 shows the results in terms of

Table 1: **Summary results of helicopter-based counts of dogs in random stratified blocks in Gauteng Province, August 1999**.

	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Total
Count 1	110	111	493	67	199	189	1169
Count 2	143	61	338	84	170	199	995
Count 3	162	114	313	83	213	224	1109

Table 2: **Count replicates** (actual data) **of dogs from helicopter-based counts of 6 random stratified blocks in Gauteng Province with standard deviation** (SD) **estimators, standard error** (SE) **terms and coefficient of variation** (CV)**.**

Count replicates			Mean	Bootstrapped SD	
1	2	3		(n_2)	(n_3)
1169	995	1109	1091	123.04	71.05

SEdiff21	SEdiff22	SEdiff23	SEdiff31	SEdiff33	CV
150.64	123.00	112.28	81.98	57.97	6.51

Table 3: **Population change as % mean** (actual counts) **and number of counts in year 1 and year 2, df, *t*-values for *t*-alpha.1** (10 % significance) **and *t*-alpha.2** (20 % significance) **and non-centrality parameters for significance tests for power** (to show % mean population change) **for dogs from helicopter-based aerial counts in Gauteng Province**.

			Mean	1091.0	Effect size (% mean)							
					0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4
				% of mean	54.55	109.10	163.65	218.20	272.75	327.30	381.85	436.40
n_1	n_2	df	*t*-alpha.1	*t*-alpha.2	Non-centrality parameters							
2	1	1	6.31	3.08	0.36	0.72	1.09	1.45	1.81	2.17	2.53	2.90
2	2	2	2.92	1.87	0.44	0.89	1.33	1.77	2.22	2.66	3.10	3.55
2	3	3	2.35	1.64	0.49	0.97	1.46	1.94	2.43	2.91	3.40	3.89
3	1	2	2.92	1.87	0.66	1.33	1.99	2.66	3.32	3.99	4.65	5.32
3	3	4	2.13	1.53	0.94	1.88	2.82	3.76	4.70	5.64	6.58	7.52

statistical power.

Review of power values in Table 4 shows that the largest power value attained is 100 % or 1.00. Considering that acceptable power levels (80 % or 0.80) are achieved using 3 counts in time *t* and 3 counts in time *t* + 1 at 10 % significance (t-alpha.1 or Type I error risk) and the method will not significantly detect a 10 % population change, only a 15 % population change can be detected with acceptable power. It must be noted that 1 – power is the Type II error risk probability. Although these values are marginal, they compare well with general findings in game censusing.[29,30] This suggests a statistically-robust method of monitoring small population changes over time. The results in Table 4 are presented graphically in Figs 1 and 2 as power curves. The power thus achieved is better than that reported by Reilly and Emslie[29] and Reilly and Haskins[30] from wildlife applications of the same technique.

Accuracy (ground confirmation)

If remote monitoring methods are to be successfully applied to planning in respect of epidemiology, then ground confirmation is essential to estimate undercount bias and thus accuracy so that a population estimate can be computed for the province as a whole. Estimates of undercount are presented in Table 5.

Undercount bias is high compared to wildlife applications, where undercount bias for most species is in the order of 20 to 60 %[17]. This is probably due to the fact that many of these animals are housed indoors. Bias is, however, fairly consistent, which also attests to robustness in the technique.

Density estimates

In Table 5 estimates of dog densities for the province in each of the high or medium density distributions are given. The confidence limits are large, but in the absence of data on densities of dogs in the province, this is a concrete estimate.

Table 4: **Power** (probability) **to significantly detect percentage population change by number of count replicates in time *t* and time *t* + 1 for domestic dogs in Gauteng Province at 10 % significance** (top) **and 20 % significance** (bottom)**.**

n_1,n_2	Population change % mean							
	5	10	15	20	25	30	35	40
2_1	0.08	0.11	0.14	0.18	0.22	0.27	0.31	0.35
2_2	0.09	0.16	0.24	0.33	0.44	0.54	0.64	0.73
2_3	0.11	0.19	0.31	0.44	0.59	0.71	0.82	0.90
3_1	0.12	0.24	0.38	0.54	0.69	0.80	0.89	0.94
3_3	0.20	0.47	0.75	0.92	0.98	1	1	1
2_1	0.15	0.21	0.28	0.35	0.43	0.50	0.57	0.63
2_2	0.18	0.29	0.41	0.55	0.67	0.78	0.86	0.92
2_3	0.20	0.33	0.49	0.65	0.78	0.88	0.94	0.98
3_1	0.23	0.41	0.61	0.78	0.89	0.96	0.98	1
3_3	0.33	0.65	0.89	0.98	1	1	1	1

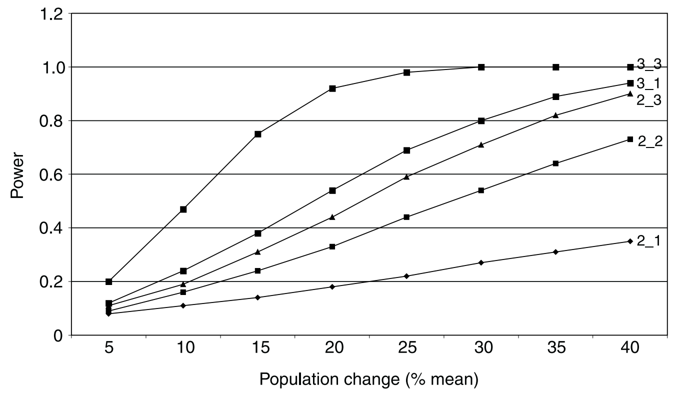

Fig. 1: **Power curves for different count replicate options to detect population change in domestic dogs in Gauteng Province at 10 % significance**.

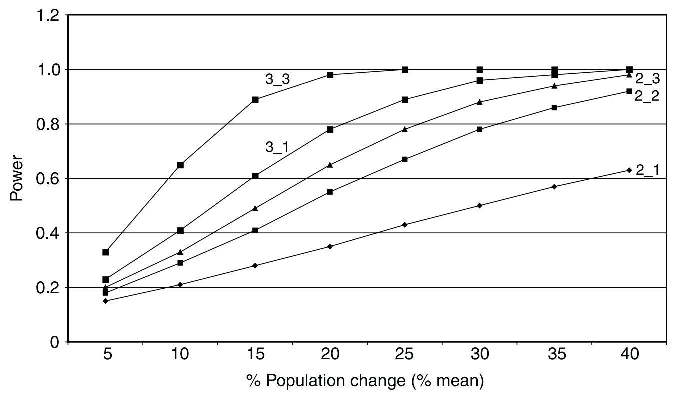

Fig. 2: **Power curves for different count replicate options to detect population change in domestic dogs in Gauteng Province at 20 % significance**.

Table 5: **Undercount bias and mean densities** (km^2) **for helicopter-based aerial counts and ground total counts for dogs in Gauteng Province, August 1999**.

Density	Aerial[a] count[a]	Ground count[a]	Accuracy %	Undercount bias (%)	Population estimate	0.95 confidence lower	0.95 confidence upper
High	260	3657	7.1	92.9	641550	447802	835298
Medium	104	1983	5.2	94.8	697226	560431	834022

[a]Mean count per census block.

CONCLUSIONS

The application of a helicopter-based counting approach commonly used in the wildlife industry has been applied to a veterinary epidemiological decision-support exercise in an urban context. Although the method has logistical advantages over the generally applied door-to-door approach, efficiency in terms of manpower and financial investment has not been determined. The method has shown high precision in the case of dogs and has shown CVs smaller than those demonstrated for most game species.

As far as dogs are concerned, densities per area and total densities coupled with GIS application will allow forward planning to counteract disease outbreaks.

As a pilot survey breaking new ground, this exercise was successful, and expansion of the programme shows promise in providing data to the proposed area framework of the Province.

ACKNOWLEDGEMENTS

The authors would like to thank all members of the air and ground teams, GIS operators and all involved for their input into the project.

REFERENCES

1. Bartmann R M, Carpenter L H, Garrott R A, Bowden D C 1986 Accuracy of helicopter counts of mule deer in pinyon-juniper woodland. *Wildlife Society Bulletin* 14: 356–363
2. Beasom S L 1979 Precision in helicopter censusing of white-tailed deer. *Journal of Wildlife Management* 43: 777–780
3. Beasom S L, Leon F G, Synatzske D R 1986 Accuracy and precision of counting white-tailed deer with helicopters at different sampling intensities. *Wildlife Society Bulletin* 14: 364–368
4. Bothma J. du P, Peel M J S, Pettit S, Grossman D 1990 Evaluating the accuracy of some commonly used game-counting methods. *South African Journal of Wildlife Research* 20: 26–32
5. Cahalane V H 1938 The annual northern Yellowstone elk herd count. *Transcripts of the North American Wildlife Conference* 3: 388–389
6. Caughley G 1979 Bias in aerial survey. *Journal of Wildlife Management* 38: 921–933
7. Cohen J C 1988 Statistical power analysis for the behavioural sciences. Lawrence Erlbaum Associates, New Jersey
8. Collinson R H F 1985 *Selecting wildlife census techniques.* Monograph 6, Institute of Natural Resources, University of Natal, Pietermaritzburg
9. Dasman R F, Mossman A S 1962 Road strip counts for estimating numbers of African ungulates. *Journal of Wildlife Management* 26: 101–104
10. DeYoung C A 1985 Accuracy of helicopter surveys of deer in south Texas. *Wildlife Society Bulletin* 13: 146–149
11. Eiselen R 1994 Estimating the trends in herbivore numbers in the southern district of the Kruger National Park. *South African Journal of Wildlife Research* 24: 95–100
12. Gad A M, Riad I B, Farid H A 1995 Host-feeding patterns of *Culex pipiens* and *Cx. antennatus* (Diptera: Culicidae) from a village in Sharqiya Governorate, Egypt. *Journal of Medical Entomology* 32: 573–576
13. Goodman P S 1977 An evaluation of three techniques for estimating animal numbers in a wildlife population. Mimeographed Report, Natal Parks Board, Pietermaritzburg
14. Graham A., Bell R 1989 Investigating observer bias in aerial survey by simultaneous double-counts. *Journal Wildlife Management* 53: 1009–1010
15. Hable C P, Namir A N, Snyder D E, Joyner R, French J, Nettles V, Hanlon C, Rupprecht C E 1992 Prerequisites for oral immunization of free-ranging raccoons (*Procyon lotor*) with recombinant rabies virus vaccine: study site ecology and bait system development. *Journal of Wildlife Diseases* 28: 64–79
16. Hirst S M 1969 Road-strip census techniques for wild ungulates in African woodland. *Journal of Wildlife Management* 33: 40–48
17. Jolly G M 1969 The treatment of errors in aerial counts of wildlife populations. *East African Agricultural & Forestry Journal, Special Issue* 34: 50–55
18. Lengerich E J, Teclaw R F, Mendlein J M, Mariolis P, Arbe G P L 1992 Pet populations in the catchment area of the Purdue comparative oncology program. *Journal of the American Veterinary Medical Association* 200: 51–56
19. LeResche R E, Rausch R A 1974 Accuracy and precision of aerial moose censusing. *Journal of Wildlife Management* 38: 175–182
20. Lipsey M W 1990 Design sensitivity: statistical power for experimental research. Sage, London
21. McCullough D R 1994 What do herd composition counts tell us? *Wildlife Society Bulletin* 22: 295–300
22. Melton D A 1978 Undercounting bias of helicopter census in Umfolozi Game Reserve. *Lammergeyer* 26: 1–6
23. Nassar R, Mosier J 1991 Projections of pet populations from census demographic data. *Journal of the American Veterinary Medical Association* 198: 1157–1159
24. Norton-Griffiths M 1978 Reducing counting bias in aerial census by photography. *East African Wildlife Journal* 12: 245–248
25. Otten M R M, Haufler J B, Winterstein S R, Bender L C 1993 An aerial censusing procedure for elk in Michigan. *Wildlife Society Bulletin* 21: 73–80
26. Payne N F 1981 Accuracy of aerial censusing for beaver colonies in Newfoundland. *Journal of Wildlife Management* 45: 1014–1016
27. Pearson E S, Hartley H O 1976 *Biometrika tables for statisticians.* Cambridge University Press, Norfolk
28. Pennycuick C J, Western D 1972 An investigation of some sources of bias in aerial transect sampling of large mammal populations. *East African Wildlife Journal* 10: 175–191
29. Reilly B K, Emslie R H 1998 Power and precision of helicopter surveys in mixed bushveld. *Koedoe* 41: 47–56
30. Reilly B K, Haskins C 1999 Comparative efficiency of two game counting techniques as applied to Suikerbosrand Nature Reserve. *South African Journal Wildlife Research* 29: 89–97
31. Rice W R, Harder J D 1977 Application of multiple aerial sampling to mark-recapture census of white-tailed deer. *Journal Wildlife Management* 41: 197–206
32. Santamaria A, Passannanti S, Di Franza D 1990 Censimento del cani randagi in un quartiere di Napoli. *Acta Medica Vetinari* 36: 201–213
33. Seber G A F 1992 A review of estimating animal abundance II. *International Statistical Review* 60: 129–166
34. Van Hensbergen H J, Berry M P S, Juritz J 1996 Helicopter based line transect estimates of African herbivore populations. *South African Journal Wildlife Research* 26: 81–87
35. Van Lavieren L P, Esser J D 1979 Numbers, distribution and habitat preference of large mammals in Bouba Ndjida National Park, Cameroon. *African Journal of Ecology* 17: 141–153
36. Virga A, Viola F 1993 Censimento della popolazione canina vagante. Esperienze nella Sicilia Occidentale. *Obiettivi e Documenti Veterinari* 14: 49–54
37. Watson R M, Razig M T A, Cadir F A 1975 The south Kordofan pilot census inventory and its application to national planning. *Bulletin, Office International des Épizooties* 84: 637–643