ESTIMATING ABUNDANCE OF AFRICAN WILDLIFE
An Aid to Adaptive Management

by

Hugo Jachmann
Environmental Council of Zambia
Wildlife Resource Monitoring Unit
Lusaka, Zambia

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The potential of low-altitude flying to collect habitat information was first recognised in the early 1920s, when aerial photographs were taken in East Africa by the Royal Air Force. Then, the objective was to collect general information on habitats and wildlife. In the late 1940s, light aircraft were used for ecological information gathering, spotting wildlife and as assistance in law-enforcement operations. It was not until the mid and late 1950s that park wardens and wildlife researchers began to use light aircraft in attempts to obtain total counts of wildlife species in East Africa. Not long after these first attempts, biologists realised that it would be more efficient to use some form of sampling rather than counting all the animals in the target population (Watson *et al.*, 1968). Furthermore, it was becoming apparent that for management purposes information on population trends was probably more useful than total numbers. By the late 1960s, low-level aircraft surveys in eastern Africa were a common practise and had developed their own distinctive character, whereby information gathered from the air was frequently related to data collected on the ground. In the early 1970s, satellite remote sensing had partly replaced aerial techniques for monitoring habitat changes. Although aerial counting techniques have always been highly overrated with regard to accuracy, they continue to be one of the many tools in wildlife management.

As with ground counting techniques, aerial techniques can be divided into total counts or censuses and sample counts or surveys. The balance between intensive total counts on the one hand and low coverage sample counts on the other hand should be considered in relation to the objectives of the census or survey, the size of the study area and the potential uses of the data to be collected. As with any wildlife count, these objectives and uses must be made clear prior to conducting the count. Although the management objective should be the single most important factor determining the type and intensity of a particular count, practice dictates that resource limitations in terms of the available time, manpower and above all the size of the budget usually bring down the management objective to a second-level priority. However, if resources are not adequate to achieve the objective, in the end it is cheaper and therefore wiser not to carry out a count that may give misleading results.

Since the 1950s, a large number of scientific papers have appeared on the subject of aerial counting, and the last thing we would like to do is to reinvent the wing. Instead, after a general overview of the theory and field procedures, we will attempt to clarify and simplify some important issues such as biases in the different techniques.

Chapter 5

AERIAL TOTAL COUNTS

The technique and the field procedures relating to aerial total counts were first summarised by Norton-Griffiths (1975). Although the concept is simple, the design of an aerial census requires careful consideration to minimise error and bias. The main objective of an aerial census is to describe accurately the total number of a particular target species, and its spatial distribution over the study area. The census requires at least two observers, each counting on a different side of the aircraft, to scan the entire study area, as the aircraft flies along parallel flight lines that are between 500 m and 2 km apart. In the case of a hippo count the observers scan rivers and pools, while for puku, reedbuck and oribi they scan dambos.

The distance between flight lines depends upon several factors. The target species, the searching rate (which is the area scanned per time unit), the height above ground level of the aircraft, the density of the vegetation and the topography of the study area are the most important ones.

Study areas larger than 1,000 km² should be divided into discrete blocks that can be covered easily by a single aircraft in one flying day. These blocks should be defined by features such as roads, water-sheds or topography.

In principle, a total count implies that there is no sample error attached to the final estimate of numbers. Unfortunately this has led to the rather uncritical acceptance of census figures, because researchers and managers have the tendency to overlook the fact that other sources of error and bias may generate unreliable results when an aerial census is not properly designed and conducted (Norton-Griffiths, 1978). A particular source of bias, known as visibility bias (see below), renders certain animal species unsuitable for any type of aerial count. A species such as black rhinoceros (*Diceros bicornis*) is impossible to count from the air with any level of precision or accuracy. In 1967 some experiments were conducted with a small rhino population, of which the numbers on the ground were known accurately, occupying the Olduvai Gorge in Tanzania (Goddard, 1967). The Olduvai Gorge is a wide open area with few scattered trees and bushes. Even under the most ideal conditions only 50% of the population was detected by observers in an aircraft. Goddard's conclusion was that light aircraft were of limited value in providing estimates of black rhino populations. Even animals as large as elephants may be

Chapter 10

FOOTPRINT MEASUREMENTS

Animal spoor or footprints per unit area can be used as an index of abundance (Van Dijke *et al.*, 1986; Koster and Hart, 1988), while footprint measurements can be used to approximate the age-structure of an elephant population (Western *et al.*, 1983), or to determine absolute density and distribution of elephant and black rhino (Kelly and Beer, 1994; Jachmann, 1984a), or large cats, such as lion, leopard and cheetah (Smallwood and Fitzhugh, 1993). Both elephants and rhinos are sufficiently heavy to render footprints visible for extended periods in a variety of soil types and habitats. When the population is small (< 40 individuals) and isolated (no migration), footprint measurements provide a means to identify individual animals. This technique may be combined with dropping measurements (circumference measurements of individual boli) to estimate abundance. Although the technique is relatively simple, leading to accurate estimates of abundance when used for small populations of solitary black rhino, its applicability for a gregarious species such as elephants is more complicated. Due to its limitations, the technique does not have a wide application in the field, but nevertheless may be useful under certain conditions. With only few small isolated pockets of black rhinos remaining in the wild, these conditions are found more frequently.

10.1 Concept, Sample Design and Analysis

Footprint measurements of fore-feet and hind-feet diameter and the difference between these (Δf), provide a means to differentiate between individuals of small isolated populations of rhinos and elephants (Jachmann, 1984a). The same applies to dropping measurements, using the circumference of individual boli of the same dung-pile (Jachmann and Bell, 1984). Rhino defecate in the same places, called middens, and tend to scatter their droppings with their hind-feet. However, they often miss a few boli, which can be measured for circumference. The technique will give reliable results when used for small populations with fewer than 40 individuals.

Observers walk along grid lines placed systematically at short intervals. Intervals or spacing between lines depends on the size of the study area, the precision required, and the funds available. A team of several observers, walking side by side with approximately 10 m between counters, covers each line on foot. Using a compass or a GPS, a dead straight line is maintained. Each team member searches the ground between himself and the next person on one side only. Footprint measurements, bolus circumference and co-ordinates of observations are recorded. Footprints should only be measured when the difference between fore-feet and hind-feet can be determined to provide Δf. Diameter of footprints is measured across the widest point between left and right toe. As an additional variable, the length of fore- and hind-feet can be measured. Bolus circumference is measured around the centre of the cylinder.

For populations with fewer than 10 individuals, frequency diagrams of footprint measurements and bolus circumference may be adequate to differentiate between individual animals. For larger populations, the information should be entered into a five-dimensional array with fore-foot diameter, hind-foot diameter, Δf, bolus circumference, and co-ordinate (longitude and latitude) of each observation as variables. As additional variables, fore-foot and hind-foot length may be entered. Using statistical software such as "Statistica" or "SPSS", a cluster analysis can be performed. With solitary species such as black rhino, the result is a series of five-dimensional clusters (seven dimensional including lengths), each representing an individual animal and its activity area. With a gregarious species such as elephants, each cluster represents a group of animals and the activity area. Multiplying the number of clusters by the approximate mean group size will give an estimate of elephant numbers.

An example of the procedure required for a population with fewer than 10 animals is the estimate we did of black rhino in Mwabvi Game Reserve in Malawi in 1983 (Jachmann, 1984a).

10.2 Field Example

In the 1970s, several researchers visited the small Mwabvi Game Reserve (351 km²) and estimated between 4 and 30 rhino (Ridding, 1975; Parker, 1976). In the early 1980s, an extension of the reserve was proposed and the authorities requested an investigation into the exact number of rhino. Because rhino mainly used the thicket vegetation, conventional techniques were not expected to provide reliable results. Instead, footprint measurements and bolus circumference measurements were used (Jachmann, 1984a).

The reserve is situated in the Lower Shire Valley in southern Malawi, on the border with Mozambique. The vegetation is a mosaic of open mixed woodland, dominated by *Albizia*, *Acacia* and *Combretum* species, interrupted by stretches of riverine thicket and small stands of mopane woodland.

Using an imaginary grid, parallel lines were placed at 1 km intervals, running from north to south and from west to east. Each line was covered by a game scout, a carrier and the author, walking side by side with 10 m between counters, giving a total line width of 30 m. Rhino spoor was followed as long as footprints could be measured. When deviating from the line of travel, the departure point was marked. Footprints and droppings were measured, preferably relating a particular spoor to the circumference of intact boli found in a midden of the same rhino. Means and standard errors were calculated for fore- and hind-feet diameter, as well as Δf, the difference between the diameters of fore- and hind-feet.

By comparing the means of the different sets of footprints measured, in combination with differences in Δf, the minimum number of rhino was estimated at 5 (Table 10.1). However, it is most likely that a few young rhino were missed, because their footprints are not as clear as those of the older and heavier animals.

Table 10.1: Mean fore-foot and hind-foot diameters with standard errors and differences between fore- and hind-feet (Δf) for 5 rhino in Mwabvi Game Reserve (Jachmann, 1984a).

	Diameter (cm)		
Rhino	**Fore-feet**	**Hind-feet**	**Δf**
1	20.40 ± 0.63	18.52 ± 0.32	1.88
2	22.14 ± 0.61	19.47 ± 0.52	2.67
3	24.06 ± 0.41	21.20 ± 0.38	2.86
4	25.50 ± 0.58		
5	18.20	16.50	1.70

Circumference measurements of 57 boli show a number of distinct peaks (Figure 10.1). Using footprint measurements found near fresh droppings, it was possible to relate bolus circumference to footprint size for rhinos 1 to 4 (Table 10.1 and Figure 10.1).

For rhino 1, circumference measurements ranged from 36 to 38 cm, for rhino 2 from 40 to 43 cm, for rhino 3 from 44 to 47 cm, and for rhino 4 from 48 to 51 cm (Figure 10.1). Regression analysis of bolus circumference on footprint diameter for rhinos 1 to 4 gave a highly significant relationship ($P<0.001$, $r = 0.997$; y (fore-foot diameter) = 6.456

+ 0.384x (bolus circumference)), supporting the classification. Bolus circumference measurements of rhinos 1 to 4, each cover a range of 3 to 4 cm. The remaining boli, with circumferences ranging from 25 to 34 cm, showing two distinct peaks and one minor peak at 27, 30 and 33 cm, probably belong to two or three unidentified young rhinos. Based on bolus circumference data, we may conclude that the reserve contained 6 or 7 rhino. Combining foot-print measurements and bolus circumference measurements, we may conclude that the reserve contained between 5 and 7 rhino.

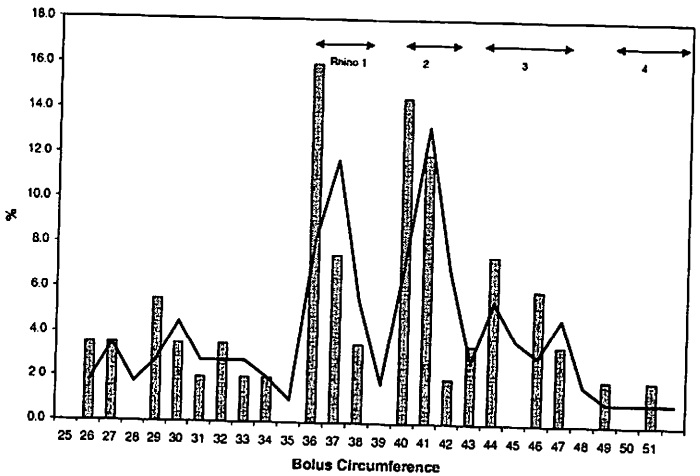

Figure 10.1: Frequency diagram of bolus circumference (57 boli) with moving average, showing the bolus circumference range for rhinos 1 to 4.

10.3 Costs of Indicator Counts

The cost of indicator counts is a function of the type of count, local salary levels, transport costs and the type of estimate required in relation to the objective. The cost of a road dropping count is the same as that of a road index count or a line-transect road count, roughly US$ 0.5 per km². The cost of a regular dropping count and a footprint survey are anywhere between US$ 0.7 and US$ 1.5 per km², depending upon the sampling intensity. Large areas will cost more per unit area than small areas, mainly because of more dead time (i.e. time lost from moving from one area to the next, and trips from and to base).

PART IV

ANALYSING DISTRIBUTION DATA AND POPULATION TRENDS

there is no need for specific management procedures, such as quota setting. In addition, including these species in an aerial survey programme is counterproductive, since it reduces the accuracy of key species estimates.

Because this manual has a heavy concentration of examples from Zambia, we will now take a closer look at selection of techniques appropriate for particular wildlife species occurring in Zambia. Most of these species also occur elsewhere on the continent.

Table 12.1 provides a summary of large mammal species found in Zambia, the average weight range for adult males and females combined, the average group size category, where S is solitary, S_m is small (<10), M is medium (10 – 30), and L is large (>30), whether Direct (D) or Indirect (I) methods should be used, and the appropriate technique(s).

As mentioned above, carnivores need to be counted with indirect techniques, such as index and radio telemetry, or with individual recognition. Under circumstances when index techniques cannot be used, assessing abundance of carnivores with the other two techniques is an expensive undertaking.

Elephants can be counted with most techniques; the appropriate choice depends on the objective and the habitat type. In the rainforest, however, the only options are dropping counts, or individual recognition for small populations.

The abundance of black rhino can only be assessed with indirect methods, such as index techniques, mark/recapture, radio telemetry, DNA analysis, faecal and footprint methods for small populations, and individual recognition, sometimes combined with mark/recapture. The abundance of white rhino, however, can be estimated with direct techniques, such as line-transect methodology.

Zebras can be counted with most direct techniques, while individual recognition may be appropriate under conditions of low density or thick vegetation.

The abundance of lechwe can be estimated with most direct techniques. However, with aerial counts, photography should be used to accurately count the individuals in large herds.

The abundance of small, mostly solitary and sedentary antelope species, such as duiker, bushbuck, klipspringer, grysbok and steenbok, and also warthog, can be assessed with line-transect methodology or faecal methods. Bushpig is a special case, where abundance can often only be assessed with particular indirect techniques, such as radio telemetry, but in some cases line transects may work.

Some of the larger herbivores, such as eland, wildebeest, waterbuck, hartebeest, roan, sable and tsessebe can be counted with most direct techniques. Line-transect methodology should be deployed in dense vegetation. However, whenever possible, cost-efficient index techniques should be deployed, such as patrol or road count indices. Estimation of kudu abundance requires index techniques, individual recognition or line-transect methodology. Although line-transect methodology can be used for giraffe, individual recognition may give better results.

Table 12.1: Large mammals occurring in Zambian conservation areas, the average weight for adult males and females combined, average group size (**S** is Solitary, **Sm** is <10, **M** is 10 – 30, **L** is >30) and guidelines as to the techniques appropriate for estimating their abundance (**D** is Direct and **I** is Indirect Technique). **All** is all direct techniques can be used, **AP** is aerial sample or total count, using photography, **FF** is faecal and footprint techniques, **IR** is individual recognition, **L** is line-transect methodology, **RT** is radio telemetry, including GPS tracking, **SG** is sample ground count, **TG** is total ground count, and **X** is index techniques.

Species	Average Weight (kg)	Group Size	D/I	Appropriate Techniques
Carnivores				
Aardwolf *(Proteles cristatus)*	11-14	S	I	X,RT,(IR)
Caracal *(Felis caracal)*	16-18	S	I	X,RT,(IR)
Cheetah *(Acinonyx jubatus)*	45-64	S/Sm	I	X,RT,(IR)
Leopard *(Panthera pardus)*	50-82	S	I	X,RT,(IR)
Lion *(Panthera leo)*	123-204	Sm	I	X,RT,(IR)
Serval *(Felis serval)*	14-18	S	I	X,RT,(IR)
Side-striped jackal *(Canis serval)*	9-10	S/Sm	I	X,RT,(IR)
Spotted hyena *(Crocuta crocuta)*	45-80	Sm	I	X,RT,(IR)
Wild dog *(Lycaon pictus)*	25-32	Sm/M	I	X,RT,(IR)
Proboscidae				
Elephant *(Loxodonta africana)*	1,500-3,000	M	I/D	All,IR,RT,FF
Odd-Toed Ungulates				
Black rhino *(Diceros bicornis)*	900-1,400	S	I/D	L,X,RT,FF
Burchell's zebra *(Equus burchelli)*	225-320	M	D	All
Even-Toed Ungulates				
Black lechwe *(Kobus leche smithemani)*	77-120	L	D	All,AP
Blue duiker *(Philantomba monticola)*	4-9	S	D	L,FF
Blue wildebeest *(Connochaetes taurinus)*	160-272	L	D	All
Buffalo *(Sincerus caffer)*	800-1,000	L	D	All,AP
Bushbuck *(Tragelaphus scriptus)*	32-77	S	D	L
Bushpig *(Potamochoerus porcus)*	55-82	M	I/D	X,RT,L
Cape Eland *(Taurotragus oryx)*	590-680	L	D	All
Cookson's wildebeest *(C.t. cooksoni)*	150-265	M	D	All
Common duiker *(Silvicapra grimmia)*	10-14	S	D	L,FF
Common waterbuck *(Kobus ellipsiprymnus)*	160-210	M	D	All
Defassa waterbuck *(Kobus defassa)*	160-272	M	D	All
Giraffe *(Giraffa camelopardalis infumata)*	900-1,200	M	D	L,X,IR,FF
Hippopotamus *(Hippopotamus amphibius)*	1,100-1,800	L	D	TG,SG,AP
Impala *(Aepyceros melampus)*	45-82	L	D	All
Kafue lechwe *(Kobus leche kafuensis)*	77-120	L	D	All,AP
Klipspringer *(Oreotragus oreotragus)*	14-18	Sm	D	L
Kudu *(Tragelaphus strepciseros)*	180-320	Sm	D	L,X,IR
L. hartebeest *(Sigmoceros lichtensteinii)*	120-145	Sm	D	All

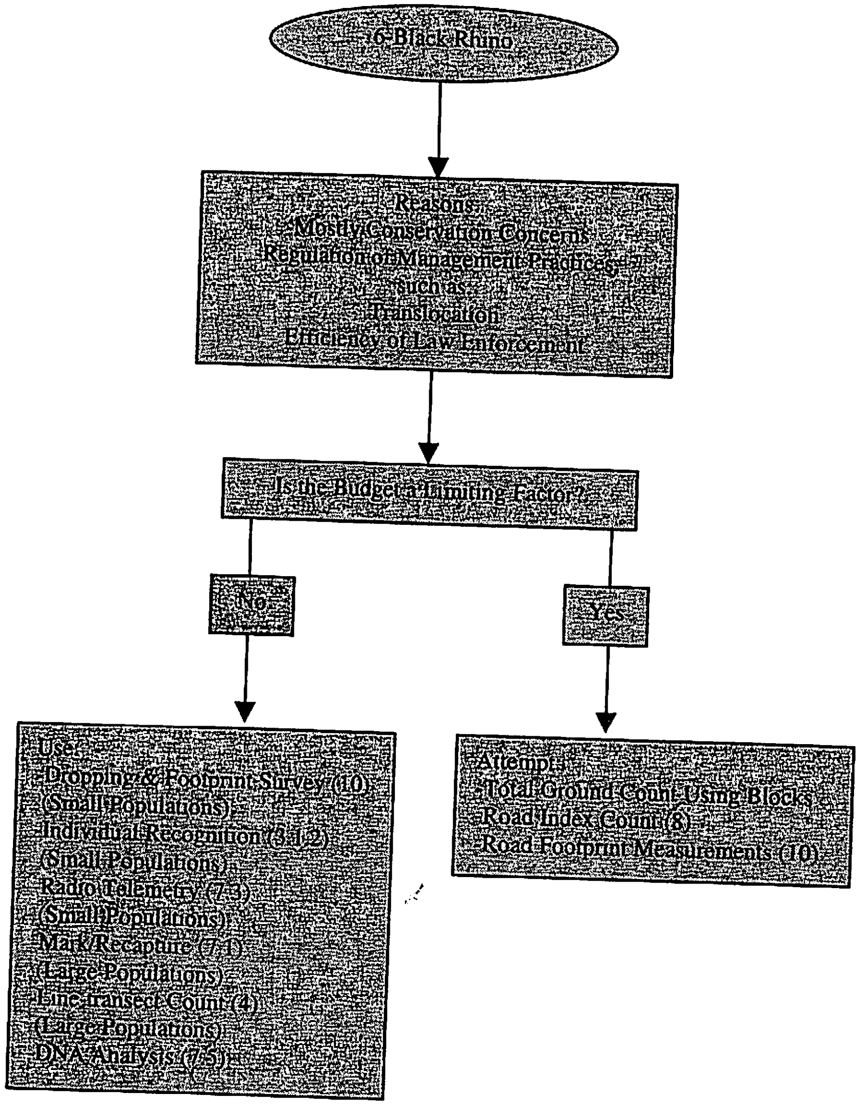

Figure 12.6: The sequence of decisions by which a technique is chosen to assess abundance of black rhino.

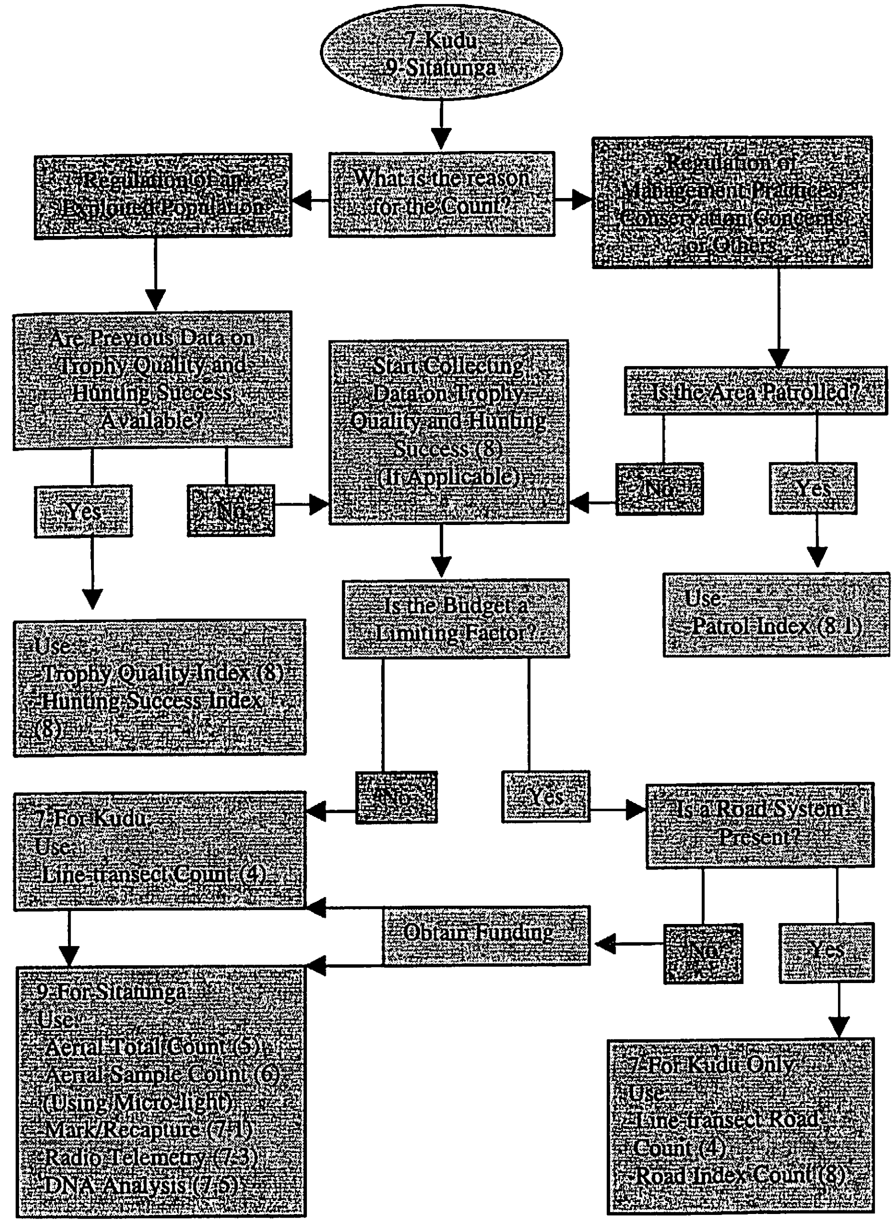

Figure 12.7: The sequence of decisions by which a technique is chosen to assess abundance of kudu and sitatunga.