Simple, terrestrial census methods for long-term monitoring of ungulates in Kuzikus, Namibia

Reinhard JE*[1], Capt C, Renevey N, Oberli F, Kuhnert E, Stoffel C

* Author for correspondence (email: j.reinhard@brink-namibia.com)
[1]BRinK – Biological Research in Kuzikus

ABSTRACT

Knowing the number of animals on natural reserves is important for sound management and conservation. On large areas with many species and large populations, it is still very challenging to obtain accurate abundance estimates using simple and inexpensive methods. The present study used terrestrial census methods for different species of large herbivores in a fenced wildlife reserve and compared them to numbers obtained from aerial counts from a helicopter of the same reserve. Terrestrial methods included road detections for animals less often seen and distance sampling. Animals were counted when driving to transects used for distance sampling and a distance analysis was employed for species with sufficient detections during transects. The abundance estimate for different species of ungulates did not significantly differ from the count obtained from helicopter counting. This implies that simple terrestrial methods employed in this study can serve as potential inexpensive and efficient methods to obtain reliable estimates of animal populations on wildlife reserves like Kuzikus.

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INTRODUCTION

Accurate assessment of larger mammal populations is crucial for the success of environmental monitoring programmes and wildlife management in natural reserves (McComb *et al.,* 2010). There are a variety of proposed methods to count animals and estimate their abundance accurately (Schwarz & Seber 1999). These techniques differ in their precision and accuracy. For example, raw counts are usually reflected by a confidence interval over 20% (Schwarz & Seber 1999) and their low accuracy can lead to a great underestimation (Gaillard *et al.,* 2003). However, in order to implement a sustainable monitoring programme and draw reliable abundance estimations of different species in an area of interest, methods need to be suitable and adaptive in the field. Hereby, not only their reliability, but also their cost-effectiveness (Gaillard *et al.,* 2003; Gaidet-Drapier *et al.,* 2003) and safety need to be considered. Furthermore, methods need to be applicable at the specific site where long-term monitoring is to be implemented as pointed out by Gaidet-Drapier *et al.,* (2003) and Hulme & Taylor (2000). This demands preliminary testing of methods that seem realistic to the conditions of the study site.

Kuzikus is a wildlife reserve situated in the Namibian Kalahari desert, dominated by *Acacia* woodland (BIOTA, 2010). It is host to a vast number of bird species, reptiles and larger herbivores indicating its ecosystem health (Skeats *et al.,* 2010, Nunes *et al., in press*, Reinhard *et al.,* 2009). The wildlife reserve aims to preserve its biodiversity and ecosystem functionality by realizing sound management. With BRinK (Biological Research in Kuzikus) populations of larger herbivores are monitored yearly.

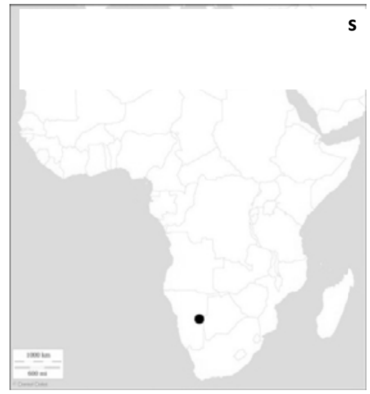
This study is part of the yearly monitoring and compared abundance estimates of simple terrestrial counting methods with aerial counts in order to draw inferences about methods suitable for long-term monitoring of larger herbivores. The main focus in terrestrial count techniques was given on distance sampling which involves the walking along transect lines throughout the reserve. This technique has a strong theoretical background based on the principle that fewer animals are detected the further away they are from the observer and can give accurate abundance estimates when there are sufficient detections (Buckland *et al* 2003).

Additionally, during data collection for the distance analysis, other terrestrial count methods included road detections and herd counts, whereby individual animals and herds were counted. These counting methods could be implemented into the study easily, as transect lines for distance sampling were randomly distributed across the reserve, and it was necessary to drive to access points. Furthermore, large but few animal herds pose a problem for a distance analysis, as herds itself as detections were not sufficient for reliable abundance estimation.

Traditional helicopter counts are often done in wildlife reserves. Unfortunately, they come with high costs and are, therefore, not performed on a regular basis. The need for inexpensive and efficient ways to count animals on large reserves is thus, inevitable.

METHODS

Study site



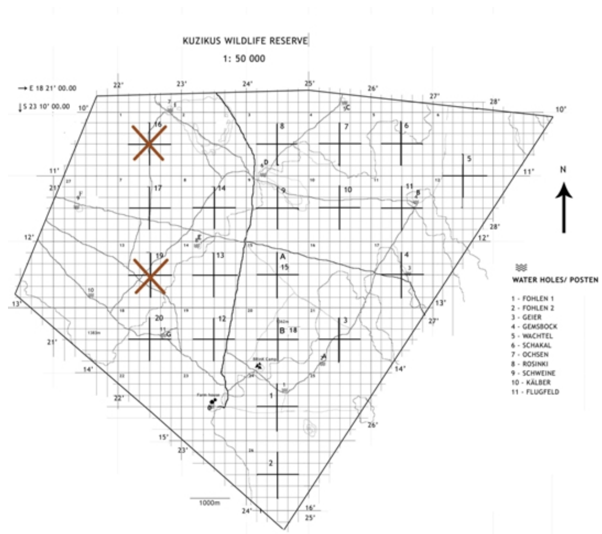
Kuzikus Wildlife Reserve is situated in the Namibian Central Kalahari Desert (Figure 1), 180km south-east of Windhoek at 1380m above sea level. The reserve is a 10000 ha fenced area, with the fence being about 2,4 meters high. Kuzikus is home to larger herbivores such as Giraffe (*Giraffa camelopardalis*), Common Eland (*Tragelaphus oryx*), Greater Kudu (*Tragelaphus strepsicerus*), Blesbok (*Damaliscus pyrgagus phillipsi*), Springbok *(Antidorcas marsupialis*), Impala (*Aepycerus melampus*), Blue Gnu (*Gonnochaetes taurinus*), Black Gnu (*Gonnochaetes gnou*), Red Hartebeest (*Alcelaphus buselaphus*), Gemsbok (*Oryx gazella*), Burchels Zebra (*Equus burchelli*), Steenbok (*Raphicerus campestris*), Common Duiker (*Sylvicapra grimmia*) and the Black Rhinoceros (*Diceros bicornis bicornis*). In general, antelopes exhibit similar herd behaviour, such as forming bachelor herds, herds of females and young and territorial males. In Zebra, the group structure comprises small bachelor herds and female herds with a dominant stallion. Wildebeest species tend to form large herds up to 200 animals varying with food abundance (Estes, 1984). Wildlife on Kuzikus is managed through hunting, game catching and translocations (*pers. comm*). The reserve is run as a tourist lodge, with no more than 10 tourists at a time. Daily game drives with a single car and walks with maximum 4 people are made throughout the reserve. Kuzikus mainly consists of the African savannah ecosystem, represented by *Acacia* (*A. erioloba, A. melifera, A. hebeclada, A. karoo)* and non-Acacia trees such as *Boscia albitrunca* and *Prosopis glandulosa (*invasive species*)*. Grasses that dominate the landscape belong the Genera *Stipagrostis* and *Aristida*.

Mean annual rainfall in 2010 was 250mm. The current study was carried out during the period of 8th September and 30rd September 2010 daily and lasting between 8:00 to 10:00 in the mornings and 16:00 – 17:30 in the afternoons. Temperatures ranged from 17.4°C to 39.4°C during field work. Humidity ranged from 2% to 38% during field work.

Distance sampling

A systematic grid was superimposed on the map of the region covering a total area of 100km^2 (Figure 2). Twenty squares of the grid (3.4 km^2) were randomly selected in which the line-transect was placed centrally. Transects were 500m apart from each other, decreasing the likelihood that an animal was counted on more than one transect. Two transects on the west side of the reserve (refer to Figure 2) were omitted due to great activity of the Black Rhino. The lenghts of lines varied from 0.39km – 1.24km at a time. Most transects were walked twice to obtain enough detections for the distance analysis and to account for varying detectability of animals. The transect length was summed for each repeat and taken as one independent sample. The total survey effort equalled 36.69 km of 18 samples. A line was walked from North-South, East-West direction depending on the accessibility to the transect from the road and the wind direction. The line- transect was walked against the wind when possible to remain undetected by animals. Transects that were walked in the morning on the first repeat were switched to the afternoon for the second repeat. This was to account for differences in animal activity/behaviour at the different times.

Prior to walking the line transects, observers were given 1 day training in basic field techniques. This included using the GPS (Global Positioning System), laser range finder and learning animal identification. During each transect, an experienced project leader was present. The sighting distance, angle, cluster size and each individual, even when in a cluster were recorded once an animal was detected. This was a modification of data collection from the previous study on animal abundance estimation in 2009. Taking the angle to the animal and sighting distance, the perpendicular distance to the line could then be calculated using the Pythagoras theorem. The angle was taken using the compass function on the GPS, the sighting distance using the range finder and each observer counted the number of animals seen. Ancillary information such as age, sex and unusual features were also recorded where possible to aid in identifying each animal or group as individual and avoid recounting on the transect. An electronic weather station was used to record the date, time, temperature and humidity for each sighting. Wind pressure (using the Beaufort scale), wind direction and cloud coverage were also estimated by the observer. Species identification and equipment use was verified by the project leader.



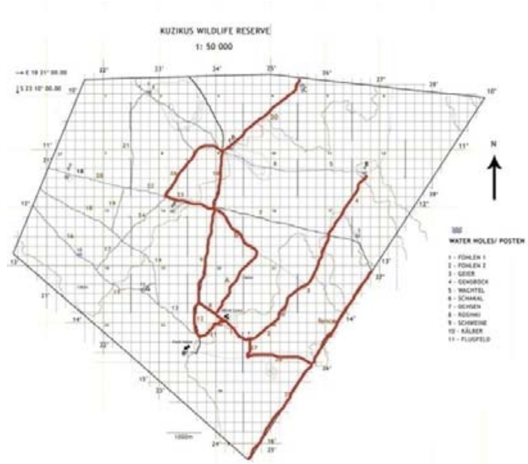
The statistical software DISTANCE 5.0 (Laake *et al* 1993) was used to estimate density of species with over 80 detections, following the analysis approach and recommendations of Buckland *et al* (2003). For the model definition properties were adjusted for each animal species analysed (Table 2). Data from the two repeats to each line was pooled as recommended by Buckland *et al.* 2001 to increase animal detections. Data was grouped into distance classes to improve model robustness (Buckland *et al* 2001). All data was right truncated by eye with a minimum of 10% of the detections. Half-normal, hazard rate, uniform and negative exponential key functions with cosine or simple polynomial adjustment terms were used to obtain a fit for the detection functions. The best fitted model was selected using the lowest Akaike Information Criterion (AIC) and high Chi-squared goodness of fit values. The aim was to make inferences about the fence area surveyed, rather than some larger study area, variance could be reduced with an overdispersion factor of 0. The best models were used to calculate density and estimate animal abundance on Kuzikus.

Abundance index

For index data, all animals that were seen on roads while driving to the line-transect were counted referred to as road detections. Hereby, not each road was taken as a sample, but rather the incidences when detections were made when driving to a line transect (i.e. sometimes several roads were driving several times a day). The mean number of detections was calculated by dividing the number of animals by the number of incidences. Furthermore the count of animals during transect was used as an index for species without enough detections for a distance analysis.

Abundance based on direct counts

Animal species were classified according to their herding behaviour to adapt methods for animals abundance estimation (Table 1). For animals that form distinct herds, abundance was based on the count of different herds that were seen during road detections and transect lines. Individual herds could often be recognised by the number of juveniles, males and females, as well as adults with i.e. abnormal horn growth. In species with low occurance, abundance was based on sightings of individuals during transects and road detections. The roads used are indicated in Figure 2.



Helicopter counts

All animals were counted from above flying transects throughout the reserve using traditional aerial methods (personal communication). The census was carried out in the beginning of dry season (May 2010) during one week in the early mornings and late afternoons. The survey involved two observers that identified and counted all animals.

Vegetation survey

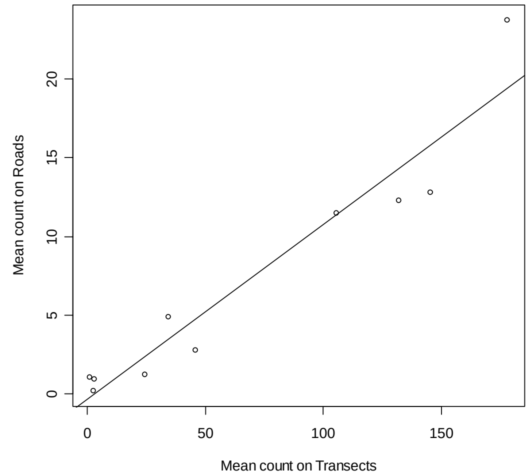
After the line transect for distance sampling had been walked in one direction, vegetation was recorded when walking back to the starting point. This was done at approximately 400m intervals, stopping 4 times to record the vegetation to give a broad description of the habitat. Dominant grass species and cover was estimated using 1m^2 quadrats 30m to each geographical direction from the interval stop. Tree and shrub species cover was estimated by counting every individual within 60m at the interval stop (approx 1ha).

RESULTS

General

In total of 18 transects were surveyed with a sample effort of 36.69km. During line transects 1341 animals of 10 larger herbivore species were detected (Table 1). In total we counted 1564 animals of 12 larger herbivores on road detections (N=21).

Mean animal counts on road detections correlated with mean counts of animals detected on transects (F=94.28, df=8, p<0.001, Figure).



Herbivore abundance estimates

Animal species were classified according to their herding behaviour to adapt methods for animals abundance estimation (Table 1). For example, animal detections in large herds cannot be used for a distance analysis, because the the number of observations would be insufficient.

	Species	Repeat 1	Repeat 2	Total	Herd behaviour
1	Black Gnu (*Connocheates gnou*)	43	26	**69**	Defined herds
2	Blesbok (*Damaliscus pyrgagus*)	100	111	**211**	Loose herds
3	Blue Gnu (*Connocheates taurinus*)	130	134	**264**	Defined herds
4	Eland (*Tragelaphus oryx*)		6	**6**	Single
5	Hartebeest (*Alcelaphus busephalus*)	46	3	**49**	Loose herds
6	Impala (*Aepycerus malampus*)	1		**1**	Herds
7	Kudu (*Tragelaphus strepsiceros*)	2		**2**	Female herds
8	Oryx (*Oryx gazella*)	183	108	**291**	Variable
9	Springbok (*Antidorcas marsupialis*)	216	140	**356**	Single
10	Zebra (*Eqqus quagga*)	37	55	**92**	Defined herds
	Gesamtergebnis	**758**	**583**	**1341**	

Table 1: Animal detections walking line transects fort he distance sampling analysis. Every transect was walked twice to increase detections.

Only the species with more that 60 detections were used in the distance analysis as recommended by Buckland *et al.* 2001. These included the Springbok (*Antidorcas marsupialis*), the Oryx (*Oryx gazella*) and the Blesbok (*Damaliscus pyrgagus*). Model definition properties are given in table. Abundance estimates for all three species are given in Table 2. Abundance estimates from different methods are summarised in Table 3.

Species	Density estimation	Standart Error	Delta AIC	%Coef of Var	Observations	Right truncation	Detection function models
Antidorcas marsupialis	0.108	0.007	0.00	5.09	329	444	HN+C
	0.155	0.013	0.35	8.98	329	444	HR+C
Oryx gazella	0.0615	0.011		17.25	251	436	HN+C
Damaliscus pyrgagus	0.0175	0.012		71.43	126	240	HN+C

Table 2: Model definition properties for Springbok, Oryx and Blesbok antelopes. HN+C= Half-normal plus Cosine adjustment and HR+C=Hazard-rate plus Cosine adjustment.

Species	Abundance estimate	Method	Helic. count	# animals removed after Helic. count
Aepycerus malampus (Impala)	1	Individual count	23	0
Alcelaphus busephalus (Hartebeest)	32	Individual count	91	0
Antidorcas marsupialis (Springbok)	1081±55	Distance sampling	1150	76
*Connocheates gnou (*Black Gnu *)*	53	Herd count	124	9
Connocheates taurinus (Blue Gnu)	126	Herd count	373	61
Damaliscus pyrgagus (Blesbok)	175±125	Distance sampling	282	60
Eqqus quagga (Zebra)	86	Herd count	155	22
Oryx gazella (Oryx)	615±106	Distance sampling	625	3
Tragelaphus oryx (Eland)	19	Individual count	24	0
Tragelaphus strepsiceros (Kudu)	23	Individual count	20	0

Table 3: Abundance estimate of ten large herbivore species occuring in the reserve using different counting methods.

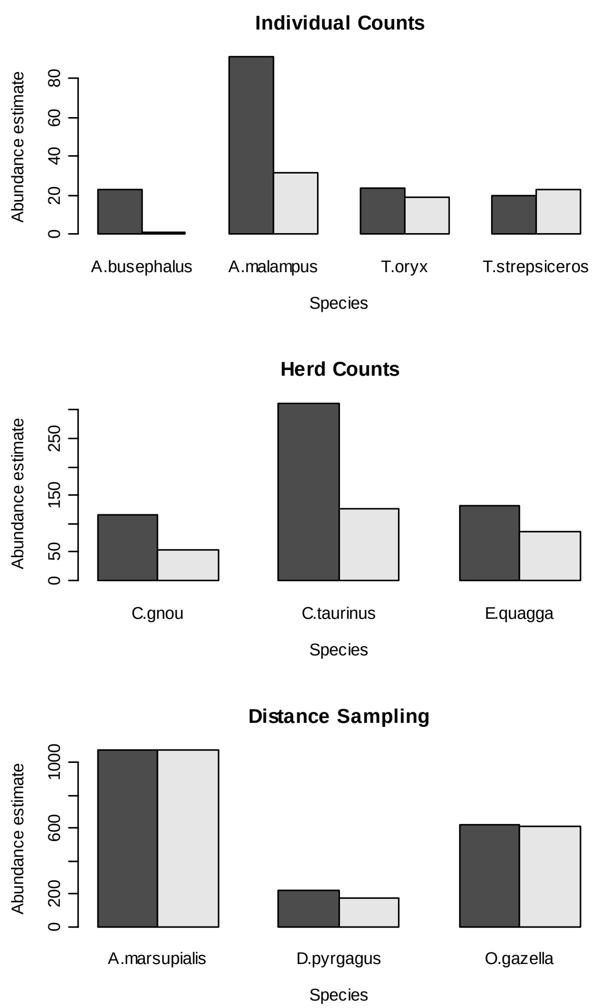


Figure 4: Species abundance estimation methods compared to Helicopter counts. Dark grey bars indicate Helicopter counts. Light grey bars correspond to the method as mentioned.

The abundance estimate obtained from each method on foot was compared with the helicopter counts (Fig. 4). Statistically, individual counts and herd counts did not significantly differ (Wilcoxon : V=1, p=0.25; V=0, P=0.25, respectively ; Fig. 4). However, note that individual counts from *A. busephalus* and *A. malampus* seem substantially lower than counts obtained from the helicopter. Likewise, especially *C.taurinus* seems underestimated using herd counting. In contrary, the results from distance sampling analysis greatly coincided, statistically and visually, with results from the helicopter count for all three species listed (distance sampling : V=1.5, p=0.586, Fig. 4).

Influence of the vegetation on animal detections

Line transects used for distance sampling were randomly selected from quadrats distributed across the whole reserve. The density of *A. mellifera* shrubs on transects ranged from 0/ha to 51/ha. Transects with a high density of shrubs could have therefore reduced the visibility to detect animals. However, the number of *A. marsupialis* detections along transects were neither affected by *Acacia erioloba* (t = 0.9205, df = 16, p-value = 0.371) nor by *Acacia mellifera* (t = -0.5579, df = 16, p-value = 0.5846) density. The same is true for *O. gazella* and *D. pyrgagus* (*A. erioloba*: t = 0.9466, df = 16, p-value = 0.3579, *A. mellifera*: t = -1.1665, df = 16, p-value = 0.2605, *A. erioloba:* t = 1.5161, df = 16, p-value = 0.149, *A. mellifera*: t = -1.3593, df = 16, p-value = 0.1929, respectively).

DISCUSSION

This study is part of the yearly monitoring performed in Kuzikus. For management implications, it is therefore to be considered in conjunction with previous reports on abundance estimation of larger herbivores (Reinhard *et al* 2009).

The results presented here demonstrate the convenience of terrestrial abundance estimation methods in relation to expensive aerial counts using a helicopter.

Density estimates were obtained from all ten target species using terrestrial counts, excluding Giraffe (*G. camelopardis*). Giraffe was encountered during road detections, from the car when driving to or from the transect line. However, their abundance was excluded from the analysis, as their numbers, like the Black Rhino (*D. bicornis*), are small and known by the manager (*pers. comm.).* The study revealed that animals counted on roads, greatly correlated with detections on transect lines. This correlation is important as it can show errors in detectability on transect lines and possible observer bias, as both methods are independent from each other (Reinhard *et al* 2009, Waltert et al 2008, Focardi et al 2002, Plumptre 2000). The large values of transect line data are likely to be the result of double counting.

Individual counts of animals were based on both, counts from road detections and counts from line transects. In the current study, it was assumed that animals were not double counted, as their detection rate itself was already low, as illustrated by the Impala (*Ae. malampus*), where only one individual was detected during the whole study period. Raw counts of *Al. buselphalus*, the Haartebeest, were much lower than counts obtained from the air. It is widely recognized that individual animal counts do not give the true number of animals present, but rather serve as an index. Even though, index data can be useful to detect drastic declines in population size, accurate abundance estimates or density per unit area are far more useful for management, as changes in density integrate changes in natural mortality, exploitation, and habitat quality (McComb *et al* 2010). In this study, however, terrestrial Kudu (*T. strepsicerus)* and Eland (*T. oryx)* counts greatly resembled the counts from the helicopter. This can be of pure coincidence, as population size is low anyways and when animals were seen during terrestrial counts, they were detected all at once. It can also be a result of undetected animals from helicopter counts, as for example the *T. strepsicerus* prefers dense bush habitat where it can remain unseen. However, no influence of the density of *A. mellifera* bush, the predominant shrub species of the area, on animal detections was found and both, *T. strepsicerus* and *T. oryx* are large animals that are not expected to remain undetected during a helicopter counts. Although it is often discouraged to base animal population numbers on raw counts (McComb *et al* 2010), they might still prove useful for large animals with low abundance. It is evident, that the West side of the reserve was not well covered for terrestrial counts (transects and road detections). This was mainly due to enhanced rhino activity and for safety reasons. The limited coverage for animal counting could therefore have caused the underestimation obtained for the Impala and the Haartebeest, both medium-sized species that tend to prefer bushy areas (Ester, 1984). Because *T. strepsicerus* and *T. oryx* counts greatly coincided with the true number of animals present (assuming that all animals were detected during helicopter counts), it might be worth designing a field protocol for terrestrial counts that covers the area throughout. In Kuzikus this should be possible considering the road network. When transect detections are too dangerous on foot, different roads can be used to and from the transect for road detections.

Even though, statistically insignificant, herd counts were, as with the individual counts, underestimated in comparison to helicopter counts. *Gnou* species usually occur in large herds (Ester, 1984). These could easily be distinguished from one another as outlined in the methods section. During herd counts, however, territorial males are dismissed in the abundance estimate which can lower the number. That might explain why the results for *Equus quagga* more similar to the helicopter count. As with the individual counts, it is recommended to increase detections by driving more roads of the West side of the reserve. Herd counts on transect might present a good method to infer information about abundance. In combination with the repeats of line transects, varying detectability is accounted for and with greater coverage of the reserve, remaining herds can be detected.

Finally, the Distance analysis revealed accurate abundance estimates for the three most common species on Kuzikus. Despite the large coefficient of variation for *D. pyrgagus* and *O. gazella* given estimates resembled aerial count quite accurately. The coefficients of variation result from the fit of the function (Buckland 2001). In the case of *D. pyrgagus* and *O. gazella*, detections closer to the line were too few and there was evidence of heaping. The half-normal plus cosine function of Distance could still give the fit for both species, working better for the *O. gazella*. Heaping occurs when animals move away from the line before detection. It is hard to attempt to detect the animals sooner. However, animals might become more habituated to humans walking along line transects in future studies. Heaping can also occur when animals form loose herds or herds of variable sizes (Buckland 2001). To deal with loose herd structures, observers are recommended to take individual detections for each animal, instead of clusters (*pers. comm.).* This was done in the current study and detection function curves were fitted much better than in previous studies (Reinhard *et al* 2009).

To conclude, Distance sampling is a powerful method to obtain accurate abundance estimates of common herbivore species. Alongside, with this sampling strategy, road detections and herd counts can be an efficient way to obtain animal numbers of animals less often seen or animals that occur in large herds.

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