Estimating elephant densities from wells and droppings in dried out riverbeds

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Abstract

In this paper, we present a new method for estimating elephant densities by counting elephant wells and dung boli within dry seasonal flooding rivers. A combination of aerial and ground counts of elephant wells and dung boli in the Ewaso Ngiro River were related to elephant numbers, obtained from an on-going monitoring program of individually identified elephants in Samburu and Buffalo Spring National Reserves, Kenya. The total number of elephant observations was highly correlated with both densities of wells and dung boli at a spatial resolution of 4-km river-section. This indicates that both wells and droppings can be used for estimating relative densities at such spatial resolution. The method can be used as a quick and reliable way of estimating relative elephant densities in semiarid regions but is sensitive to differences in the time when different parts of the river dry out and will be unreliable in areas with secondary un-censused water sources. A short 4-week period between the river dry out and the count is recommended, because of an error induced by a level of well reuse and the difficulties in counting areas of high well densities from the air.

Key words: aerial count, dung count, elephant densities, seasonal rivers, transect, wells

Résumé

Dans cet article, nous prèsentons une nouvelle méthode pour estimer des densités d'élèphants en décomptant les puits et les crottins à l'intérieur de fleuves secs saisonniers. Une combinaison de décomptes aériens et terrestres dans le fleuve Ewaso Ngiro furent rapportés au nombre d'élèphants établi par un programme de surveillance continu des éléphants individuellement identifiés au Samburu et dans la réserve nationale de Buffalo Spring, au Kenya. Le nombre d'observations d'élèphants fut fortement lié à la densité de puits et de crottins à une résolution spatiale de 4-km section-du-fleuve. Ceci indique que les deux peuvent être utilisés pour estimer les densités relatives à une telle résolution spatiale. Cette méthode peut être employée comme façon rapide et facile d'estimer des densités d'élèphants relatives dans des régions semi arides, mais est sensible aux différences temporelles quand les parties du fleuve sont asséchées et ne sera pas fiable dans des zones avec sources d'eau secondaires non-recensées. Un court intervalle de 4 semaines entre l'assèchement et le décompte est préconisé, à cause d'une erreur provoquée par le réutilisation de puits et les difficultés implicites dans le dénombrement de fortes densités de puits de l'air.

Introduction

Getting reliable information on the number and density of elephants in often remote and inaccessible regions are important for both conservation, wildlife management and as a background for scientific questions. A number of different methods are available ranging from aerial surveys (Ottichilo, Kufwafwa & Stelfox, 1987) to dung counts (Barnes, 1993, 2001) and ranging in accuracy from assessing relative densities to estimating absolute numbers. Estimating the total number of elephants from counts of droppings is both time consuming and needs to incorporate differences in defecation rates between seasons and changing rates of decomposition because of factors like rainfall and insect activity (Jachmann, 1984; Barnes & Barnes, 1992). Total or census aerial counts have been used successfully, but are carried out infrequently because of the high costs involved in covering large areas by plane.

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Many elephant populations throughout the African continent are found in semi arid regions where available water sources are limited for prolonged periods of the year. When the seasonal flowing rivers dry out after the rainy season, elephants are often forced to dig for water in the riverbed if no other sources of water are available in the area. Often they are confined to areas along the rivers because of water constrains (Viljoen, 1989).

When a river ceases to flow it leaves a clean transect through an area with no droppings or wells. With time, the number of wells in the river increases as will the number of droppings left during the period used for drinking. If the number of droppings and wells in the river are correlated to the density of elephants, a count of wells and droppings could be used as a method to estimate relative densities of elephants. If the numbers of wells or droppings are linearly related to the density of elephants such count of wells and droppings will be directly comparable between different sections of the census area. The number of wells and dung boli will be a measure of 'elephant days' spent in the area around a part of the river. Hence, it cannot differentiate between x elephants in 1 day and one elephant in x days. Therefore such a census will reflect the level of utilization of an area by elephants. However, if the level of utilization of an area also reflects the actual number of different individuals such a census could potentially be used to estimate number of elephants if the numbers of wells and droppings elephants produced per time unite can be estimated. This could be the case if the period between the drying out of the river and the count is short relative to the movements of the individual elephants, i.e. individual elephants stay to a large extent within the same area during this period. This in term will depend on the resolution of the count, i.e. the distances of the river that are counted as one section (area).

The advantage of this potential method is that a smaller area, the river, has to be counted compared with census counts over large areas in traditional dung count or aerial census of elephants. The period where the dung and the wells have been produced is known and no significant decomposition of the dung has taken place if the count is carried out <2–3 months after the river has seized to flow (Jachmann, 1984). The count could possibly be carried out from the air, covering large areas in short time with less flight time compared with direct aerial counts of individuals.

Certain assumptions have to be met for the method to be reliable. (i) No other major/heavily used un-censused water sources must be available to the elephants within the census area. (ii) If the number of droppings is used for the estimate, all elephants must on average spend the same amount of time drinking and not spend a significant time in the river when not drinking. (iii) If the number of wells is used as an estimator the effect of a potential reuse of wells must be assessed.

Information on water availability in the area must be accessible to test assumption (i). As elephants drink daily and seldom venture further away than 10 km from water, potential watering points within a 10-km 'buffer zone' of the census area should be covered. Elephants do not spend time in the river sand unless drinking or mud bathing and normally spend between 30 and 45 min digging and drinking (Pers. obs. H.B. Rasmussen). Elephants do sometimes reuse wells. However, if a simple fraction of wells is reused per unit time, the relationship between the number of wells and elephant density may remain linear. If well reuse is a function of density of wells already present in the river, the relation between number of wells and density of elephants will become nonlinear as well reuse becomes more frequent in areas with high densities of elephants. If the later, minimizing the time from the river dry out until the count could reduce this effect, as fewer existing wells will be available.

In order to test the validity of this method the counts of wells and dung must be related to a known count of elephants present in specific areas. Such a chance occurred when the semi permanent Ewaso Ngiro River ceased to flow on the 19th of January 2000. This river runs through the core study area of the Save the Elephants monitoring programme where detailed knowledge on occurrence of individual known elephants is being collected continuously.

A combined aerial and ground count was carried out to investigate the relations between number of wells and droppings and the density and number of elephants in an area. Based on these results we evaluate if this method of river counts is feasible and if such counts can be carried out from the air.

Material and methods

Study area and population

The study area is situated just north of the equator on longitude 37°, in and around Samburu and Buffalo Springs National Reserves, Kenya. The area consists of low-lying semi-arid rangeland along the Ewaso Ngiro

River, a semi-permanent river in the area. The river is the only available water source during the dry season apart from two small springs and a tributary, which elephants rarely use for drinking in the south-eastern part of the Buffalo Spring National Reserve. The total elephant population within the greater Laikipia/Samburu area has been estimated to 5000 individuals (Omondi *et al.*, 2002). Of those, approximately 800 are using the area in and around the national reserves (Wittemyer, 2001) and have been identified individually by the Samburu Elephant Research Programme (SERP), a long-term research project carried out by 'Save the Elephants' in Samburu and Buffalo Springs National Reserves.

A total distance of 55 km was covered with 20 km inside the reserves and 35 km outside. Fifteen kilometre of the river within the reserves lying adjacently to the springs was not included in the count. The count of wells and dung boli was carried out between the 7 and 11 March 2000, 7 weeks after the river ceased flowing.

Elephant number and density

Data on the presence of individually known elephants within the reserves are continuously recorded by Save the Elephants ongoing monitoring programme using on-ground observations within the borders of the two reserves recording position, group composition and identity of all elephants encountered. In case of multiple observations of the same individual elephant on the same day only the first observation is recorded. A minimum of 20 field days is spent per month, hereby recording all elephants spending a significant time within the reserve (Wittemyer, 2001). Only observations from the 7-week period between the river dry-out and the count were used.

The number of single observations (including multiple observations of the same individual but on different days) was used as a measure of elephant density reflecting the relative use of an area by elephants. The number of different individuals seen during the 7-week period within a given area was used as a measure of number of different elephants utilizing that area.

Ground count

Dung boli and wells were counted in 500-m sections of the river by driving slowly in the riverbed. The position between each 500-m section was taken using a GPS. Single elephant defecation consists on average of three to six boli. Dung was counted as the number of boli and not as number of defections as it was impossible to distinguish individual defections in some areas. No signs of significant dung decay were evident (all groups of boli was fully recognizable) because of the dry conditions in addition to the short 7-week period between river dry-out and the count. An attempt was made to distinguish between fresh and old wells. The time period from a well was made until it was regarded as old could however not be well established. Furthermore, we assumed that no wells had disappeared because of age during the 7 weeks prior to the count.

Two types of ground-counts were carried out (Fig. 1a). (i) A total count where all boli and wells occurring in the

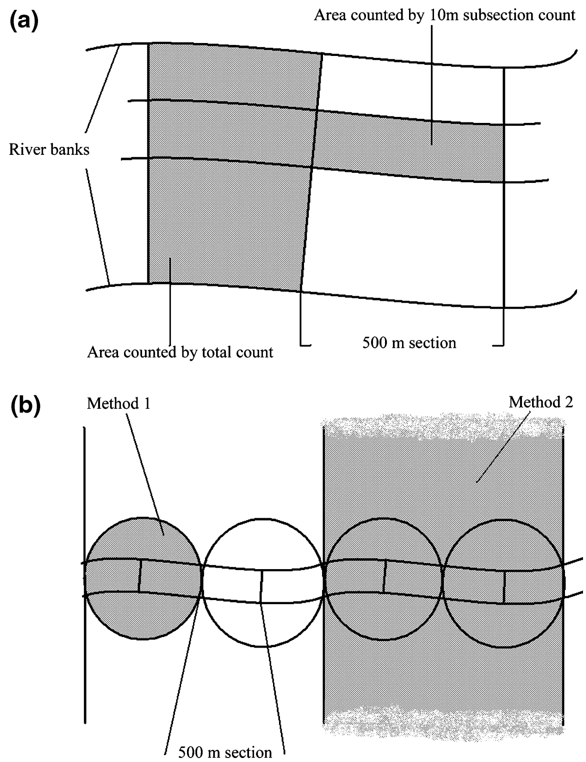

Fig 1 Counting methods: (a) Number of wells and dung boli were summed in sections of 500-m. The total count included all wells and dung boli within the river. The 10-m subsection count included only wells and dung within 5 m on either side of the car. (b) Spatial methods used: Method (i): the counts of two subsequent 500-m sections were summed and related to the observations of elephants lying within 500 m from the position separating the two sections. Method (ii): The counts from four subsequent 500-m sections were summed and related to the elephant observations lying between the first and last longitude of the combined section. Method (iii): The number of sections were doubled to eight compared with method (ii)

river was recorded (ii) A 10-m wide subsection count where 5 m to each side of the car was counted. Elephants sometime stand on the edge of the river browsing on overhanging branches. Hence leaving defecations at the river edge during periods not associated with drinking. Such spots of several dung piles next to a browsed branch/tree are easy to recognize. However, to avoid such a riverside effect on the subsection count we kept the car between 15 and 20 m from the northern riverbank. These defecations associated with browsing spots where also not included in the total count. The subsection count was carried out over the entire 55 km. Only 35 km was covered by the total count as rain on the day of counting could have flooded the river, hence the more time-consuming total count was abandoned to speed up the counting.

Aerial count

A total count of wells was carried out from the air using a Cessna 185. The flight path was kept approximately 50 m adjacent to the river, giving the observer full view of the river. The count were recorded every 15 s. corresponding to approximately 700 m of river. The positions separating the counting sections were taken automatically with the flight GPS. A total of 35 km of the river were covered by air corresponding to the 35-km where both total and subsection counts were carried out (Fig. 2).

Analysis

Comparison of counting methods and counts of wells and boli

Aerial and ground counts of wells were compared from the 35 km of the river where both a total ground count and an aerial count were carried out. This was performed in order to evaluate if the two counting methods gave identical results. The positions separating each counting section were not identical between the ground and air count as the flight path had to be kept adjacent to the river in order to have full view. Further, the aerial counting sections had to be specified in time units compared with distance on ground. However, corresponding positions between aerial and ground counts, separated by <50 m, occurred every 3–4 km. The results from the total ground count and the aerial count of wells where compared between such seven larger sections.

The number of boli and wells counted in each 500-m section was compared between the subsection and total ground count to evaluate how the subsection count reflected the total number of boli and wells in the river. The comparison between aerial and ground count and total and subsection ground counts was an evaluation of counting methods on the same sections of river hence the relation was expected to be linear and the comparison was carried out by regressing aerial count against ground counts and total count against subsection count. The

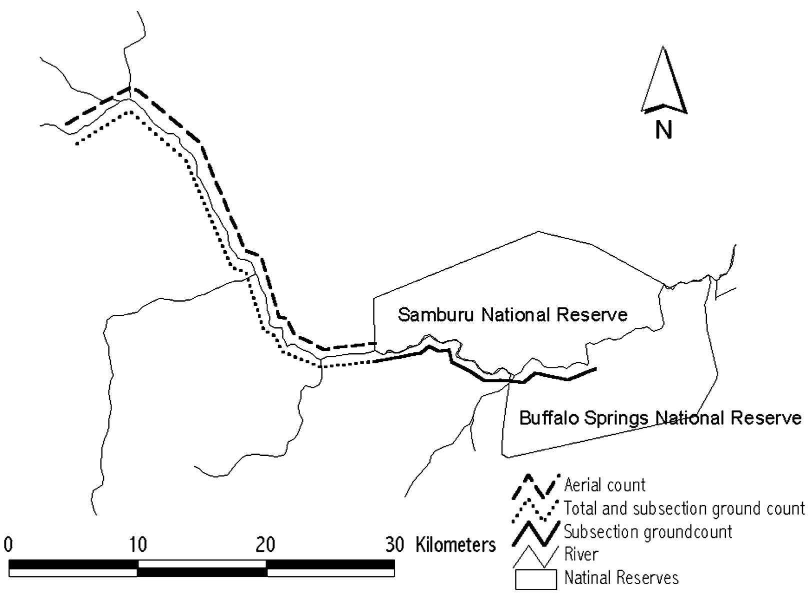

Fig 2 The sections of the river where different types of counts were carried out

counts of boli and wells were compared within each 500-m section of the 10-m subsection count using Spearman rank correlation.

Elephant observations versus well and dung counts

Only the 10-m subsection count of wells and dung boli were obtained from within the reserves. The number and density of elephants were therefore compared with the 10-m subsection count of wells and dung boli along the 20 km of the river within the reserve boundaries where elephant observations were available. The total number of all elephant observations within a specified area during the 7 weeks from the river dry out until the count was used as a measure of elephant density. The number of different individuals observed during the 7 weeks was used as a measure of number of elephants.

We tried out three different spatial methods of relating the elephant observations to the number of wells and dung boli to evaluate at which spatial resolution a close relationship between the number of wells or dung boli and the relative density of elephants would potentially emerge and to evaluate if the density of elephants also reflected the number of different individuals.

Spatial methods

1 The numbers of wells and dung boli were summed up for non-overlapping sections of 2 × 500 m. These values were assigned to the GPS position separating the two 500-m sections (center position). Elephant observations within a 500-m radius of that center position were counted using Arc View (Fig. 1b).
2 The numbers of wells and dung were summed up for non-overlapping sections of 4 × 500 m (2 km of river) and related to number of elephant observations between the longitudes of the section borders and approximately 8 km on either side of the river, corresponding to the area covered by the monitoring programme (Fig. 1b). The grouping of observations using longitudes could be justified as this part of the river runs almost straight from west to east making the sections non-overlapping.
3 Same as method 2 except the sections were doubled to 8 × 500 m (4 km of river).

The relation between the relative density of elephants and number of different elephants as well as the relations between relative density of elephants and the number of dung boli and wells could not be assumed to be linear and was compared using spearman rank correlations. The shape of the relation was evaluated by comparing the correlations of both linear and nonlinear trend lines. These trend lines were forced through origin, as zero elephants would be expected to correspond to no wells or dung boli.

Results

In Fig. 2, a map of the area indicating the different types of counts carried out are shown. Large differences in the number of wells and boli were observed along the 55 km of river both between general areas and between subsequent counting sections (Fig. 3). This indicates general differences in elephant densities and specific points used for drinking along the river.

Aerial counts of wells were hard to obtain when densities exceeded approximately 150 wells per 500-m river. This prevented aerial counting of the 20-km of river inside

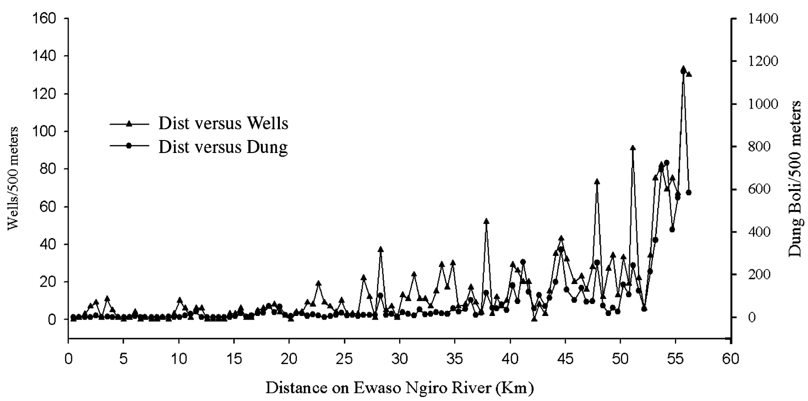

Fig 3 The number of wells and dung boli per 500 m counted in the 10-m subsection count on the 55 km of the Ewaso Ngiro River

the reserves. It was not possible to count dung boli from the air.

Comparison of counting methods

The total aerial count was regressed against the total ground count. The two total counts where significantly correlated (air count = 1.96 × ground-count, $P = 0.005$; n = 7 $R^2 = 0.73$) but with aerial counts being twice as high as the ground counts. This discrepancy is probably because of an underestimation in the ground count where wells situated far from the car on the 80–100 m wide river could have been difficult to detect. This underestimation is not expected to have influenced the 10-m subsection count as the 5 m on each side of the car were in clear view.

The ground total count was regressed against the ground subsection count for both wells (total count wells = 2.46 × subsection count wells + 1.61, $P < 0.001$; n = 71; $R^2 = 0.79$) and boli (total count boli = 2.64 × subsection count boli + 7.52, $P < 0.001$; n = 71; $R^2 = 0.76$). In the subsection count, the number of wells was significantly correlated with the number of dung boli (Spearman rank $t = 12.95$ $P < 0.001$; n = 111; $r = 0.72$) The number of boli had a tendency to increase faster than the number of wells, revealed by a better fit using a polynomial fit [wells = (0.043 × boli^2) + (2.6 × boli), $R^2 = 0.83$) compared with a linear fit (wells = 5.80 × boli, $R^2 = 0.75$).

Elephant observations versus well and dung counts

For methods (i) to (iii) the number of observations of elephants (density) was significantly correlated with the number of different individuals (Spearman rank, $r = 0.9$–0.97, n = 5–20, $P < 0.05$) but for method (ii) and (iii) a nonlinear relation was apparent (Fig. 4). In method (i), the number of dung boli and wells within a 1-km section of the river were compared with elephant observations within a radius of 500-m from the mid point of the 1-km section. Using this spatial scale both the number of wells and boli was significantly correlated with both the density (total observations) and number of individuals (Spearman rank, $r = 0.51$–0.61, n = 20 $P = 0.02$–0.007). However the variation was large (Fig. 5a). When using larger 2-km sections of the river in method (ii), similar results where obtained (Fig. 5b). In method (iii), the 2-km sections used in the second method were doubled to sections of 4 km of river. Using this spatial resolution the number of sections where reduced to five, too few to use a spearman rank correlation for assessment. This method was therefore evaluated by assessing the correlation coefficient of the trend lines (Fig. 5c). A nonlinear relation between the number of wells and density of elephants was evident with a polynomial fit explaining more of the variance [density = (0.0017 × wells^2) + (0.49 × wells), $R^2 = 0.99$] compared with linear (density = 1.38 × wells, $R^2 = 0.88$) whereas the relation between number of individuals and wells were equally explained by linear (individuals = 0.65 × wells, $R^2 = 0.95$) and polynomial fits [individuals = (0.0003 × wells^2) +(0.50 × wells), $R^2 = 0.97$]. The relation between both the density and number of elephants versus dung boli appeared to be linear with the linear trend lines explaining most of the variation (density = 0.23 × boli, $R^2 = 0.99$; individuals = 0.10 × dung, $R^2 = 0.89$).

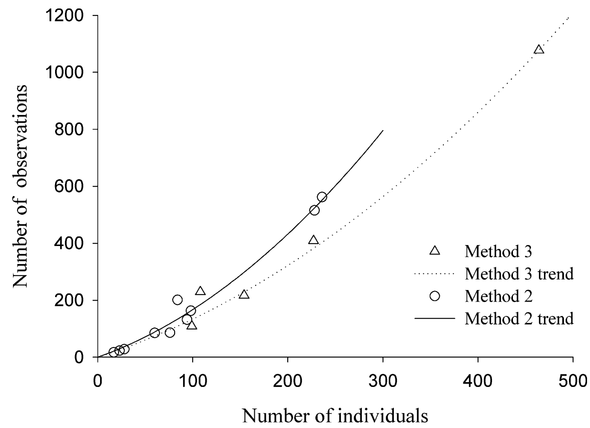

Fig 4 Number of observations (measure of density/utilization) versus number of different individuals using method (ii) and (iii)

Discussion

The total and subsection ground counts was significantly correlated however the subsurface water was meandering in the riverbed causing the 10-m count to miss the highest densities at intervals indicating that total counts are preferable. The total aerial and total ground count of wells was also correlated however the ground count generally had a lower count compared with the aerial count. This is probably because of a too low count in the ground count where wells could be difficult to detect on the 80–100 m wide river.

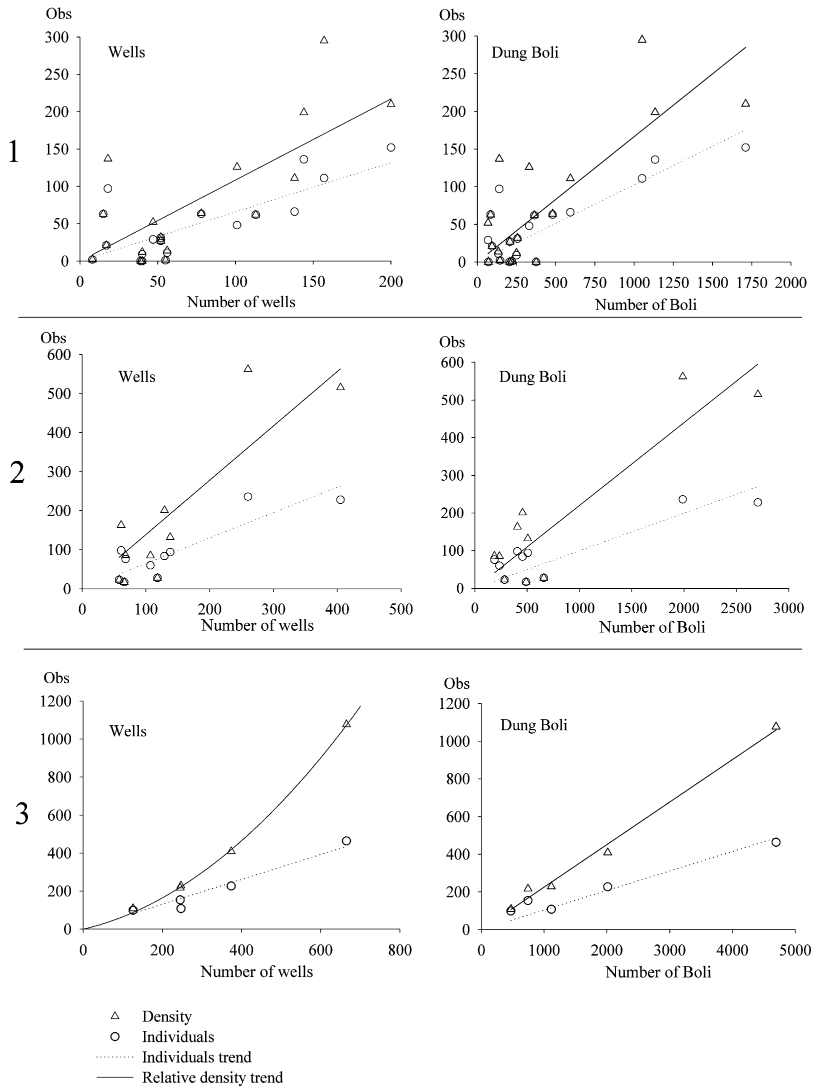

Fig 5 The number of elephant observations and the number of different individuals observed versus the number of wells and dung boli counted in the 10-m subsection count using (a) method (i), (b) method (ii) and (c) method (iii)

Elephants migrate on a daily basis 3–5 km to and from the river covering 8–10 km per day searching for food and water (Pers. obs. and GPS tracking). Therefore it was not surprising that a low correlation existed between the number of wells, dung, and number of elephant observations (the measure used for density) when a fine-scaled spatial resolution of 1 and 2-km river-sections was used. However, the subsection count of wells, dung boli and the number of elephant observations where similarly ranked when using larger 4-km river-sections and with the trend lines explaining most of the variation. This shows that a comparison of the number of wells or dung boli between river sections can be used as a measure of the relative densities of elephants along rivers at this spatial scale. The number of wells showed a nonlinear relation to the number of observations. This is probably linked to a level of well reuse, which is also reflected in the nonlinear relation between the numbers of boli and wells over the whole distance counted. The relation between number of dung boli and density of elephants appeared to be linear hence the count of boli may be directly comparable between areas.

The number of wells and dung boli was also correlated with the number of different individuals observed within the 4-km sections of the river. However, several family units left or arrived at the reserve during the 7-week period and many of the elephants utilized more than one of the 4-km sections. In addition the nonlinear relation between number of observations and number of different individuals indicate that areas with high numbers of different individuals recorded had relatively higher numbers of observations. This may be due to these areas both attracting larger numbers of individuals but with individuals in addition staying longer in these areas. Hence currently the presented method can only be used for assessing relative densities.

The big advantage of using well counts instead of dung counts is the ability of aerial counting. By using aerial counting large areas can be covered in a short period as well as areas inaccessible from the ground. The higher number of wells seen from the air compared with the ground indicates that aerial counting may be more accurate than total ground counting. Therefore, total counts on wide rivers are recommended to be performed either by two or more teams each counting a part of the river or by aerial counting. The linear relation between the number of observations and the number of boli indicate that the count of boli may be advantageous over counting wells as boli counts can be directly compared between areas.

Counting areas with a high density of wells turned out to be difficult from the air, which suggests using a period between the drying of the river and the count shorter than the 7-week used in this study, especially in areas with high elephant densities. Other advantages of a shorter period is a lesser degree of well reuse and a general lower number of wells or dung to be counted, making the count easier.

The present study has shown that counts of wells and dung boli in dry seasonal flowing rivers can be used as a fast and relatively cheap way of estimating relative densities/level of utilization of elephants in semi arid regions. Further studies are needed before it can be evaluated if the presented method can be used for estimating actual numbers of elephants.

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