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First assessment of age and sex structures of elephants by using dung size analysis in a West African savannah

[1] *Université Ouaga 1 Professeur Joseph KI-ZERBO/CUPD, Laboratoire de Biologie et Ecologie Animales, 09 B.P. 848 Ouagadougou 09 - Burkina Faso Corresponding author, E-mail: hema.emmanuel@yahoo.fr*

[2] *Ecologia Applicata Italia s.r.l., via Edoardo Jenner 70, Rome, Italy*

[3] *IDECC - Institute for Development, Ecology, Conservation and Cooperation, via G. Tomasi di Lampedusa 33, I-00144 Rome, Italy; and Department of Applied and Environmental Biology, Rivers State University of Science and Technology, P.M.B. 5080, Port Harcourt, Nigeria*

Emmanuel M. Hema[1], Massimiliano Di Vittorio[2], Fabio Petrozzi[2], Luca Luiselli[3], Wendengoudi Guenda[1]

ABSTRACT

1. An age and sex structure study of the West African savannah elephant (*Loxodonta africana africana*) population of the Nazinga Game ranch (Burkina Faso) was carried out using direct sightings of individuals near water points, where they group during hot periods of the day, and droppings circumference measurements of dung pile along line transects, during the dry seasons of 2007 and 2008. The age structure, from direct observation data, was estimated by classifying the individuals into 9 age-class-categories based on body size and eruption (length) of tusks.
2. The frequency distribution of number of individuals into the age-class-categories showed high similarity with the distribution of circumference measurements of dung-piles that the individuals were seen depositing. Fifty dung-piles measured soon after they were deposited (Class A) and after they dried (to class C) showed a significant difference between the circumference measurements in relation to the time elapsed between the measurements.
3. The frequency distribution of dung circumference classes of the observed elephants was similar to that of the dung-piles measured along the transects in 2008. Therefore, dung-piles measurements were used to estimate the Nazinga Game Ranch savanna elephant population's age and sex structures at the end of dry seasons of 2007 and 2008. We advocated that the Nazinga elephant population consisted mainly of sub-adults.
4. The sex ratio was estimated to be in favour of females (1/2). The age-class-specific sex ratio was uneven for calves and young individuals, while being in favour of females with adults. Individuals of less than 1 year represented 6% of the population during the study period.

KEYWORDS

African elephant, age structure, sex ratio, dung circumference analysis, Burkina Faso.

INTRODUCTION

Effective ecological monitoring of an animal population implies good knowledge of its spatial as well as temporal dynamics (e.g., Dublin & Taylor 1996). Achieving this goal requires knowledge of the population demographic parameters (e.g., Galimberti et al. 2001). For example, knowledge of the age structure is fundamental to study the dynamics of a population as well as to take appropriate decisions for its management (Sukumar 1992; Dublin & Taylor 1996). A healthy and growing population will show a high proportion of young individuals with a gradual and steady decline of the adult classes, with considerable fluctuations in the ratios of juveniles/adults being not uncommon (e.g., Hailey et al. 1988; Filippi et al. 2010). For instance, in mammals, it has been observed that after a year of severe drought, the percentage of calves for a given year may be brusquely higher than that of previous years (Moss 2001). If the proportions of adults are consistently higher than juveniles, there should probably be a breeding and/or young survival problem and a big chance that something is going wrong in the habitat (Laws 1969; Whyte 1996; Filippi et al. 2010).

A remarkable suite of different field techniques has been used to estimate the age and sex population structures in the wild animal populations (Hammond et al. 1990; Nussey et al. 2008; Skalski et al. 2010; Eggert et al. 2014). With regard to large mammals (e.g., elephants *Loxodonta africana*), age and sex population structures have been estimated by aerial or ground surveys using various methods, such as the analysis of individual carcasses and/or lower jaws, individual recognition, direct sightings with measurements of shoulder height, back length, length of digital food print and dung/faeces size (circumference) (Laws 1966; Croze 1972; Corfield 1973; Douglas-Hamilton 1973; Laws et al. 1975; Leuthold 1976; Jachmann & Bell 1984; Poole 1989a; 1989b; Lindeque 1991; Lee & Moss 1995; Moss 2001; Morrison et al. 2005; Stansfield 2015). Recently, the mammal three-dimensional photogrammetry, which uses camera images to get not only biometrics but also

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the animal volume (3D models), proved to be effective on large ungulates, and was useful also at water bodies where these animals used to gather and spend considerable time (Postma et al. 2016). However, the use of this technique is expensive in general, and particularly in a developing country like Burkina Faso, and is also logistically difficult to work out with elephants that can easily damage or even destroy the equipment.

For field studies of the elephants in the West African sub-region, the implementation of each of these methods still raises substantial economical as well as technical skills concerns. Meanwhile, the West African savannahs provide suitable conditions for using the method of dung circumference measures; indeed, when elephants spend several hours in the dense vegetation, the dungs remain in place and become available for study, once the elephants leave. Indeed, the analysis of dungs is noteworthy because it also gives insights into the sex structure of the population under study. There is a sexual dimorphism in the size of elephant dung; after 8 years, males produce much larger droppings that females of the same age (Jachamnn & Bell 1984). For example, a given bolus could come from a male of 16 years or a 28 years old female (Jachamnn & Bell 1984). Furthermore, it was shown that the size of the bolus is strongly positively correlated to age (Jachmann & Bell 1984; Reilly 2002; Morrison et al. 2005). The dung-pile measurements collected from surveys provide data on the structure of the population or more strictly on the size distribution of the population (Hema 2012).

Here, in order to improve our knowledge of the West African savannah elephants, we apply the method of dung circumference measurements coupled with individual recognition to assess age and sex structures of the elephant population parameters of Nazinga Game Ranch in southern Burkina Faso. We not only analyse the feasibility and efficacy of this technique with West African savannah elephants, but also analyse the ecological correlation of age and sex structures of one of the most important savannah elephant population of the sub-region.

1. METHODS AND MATERIALS

1.1. Study site

The field study was carried out at Nazinga Game Ranch (about 940 km^2 surface; coordinates: 11°1’-11°18’ N, 01°18’-01°43’W), a protected area of south-central Burkina Faso (West Africa) (Figure 1). Nazinga is situated in the Soudanian zone (Founier 1991), and in the East Black Volta phytogeographic district of the southern Soudanian sector (Guinko 1984), where the climate is characterized by a dry season running from October to May and a rainy season from June to September. The mean annual rainfall is about 900 mm. The vegetation is tall grass tree/shrub savanna, showing mainly riverine forest, savanna woodlands and shrub savanna (Guinko 1985). The Nazinga Game Ranch is a protected area and harbours one of the most important savanna elephant populations in West Africa (Blanc et al. 2007; Bouché et al. 2011; 2012). According to Hema et al. (2009), the estimate of the elephant population by means of direct foot count along line transects was 2,173 (95% confidence interval: 882, 5355).

Figure 1. Map of Burkina Faso showing the study area (Nazinga Game Ranch).

1.2. Protocol

1.2.1 Direct observations in the field

Individuals or groups of elephants of different age classes and sex were directly observed in the field from January to March 2008. These months were selected because they represent the peak of dry season, that is the period when droppings have a lesser % decay per time unit, and therefore, they can be most easily analysed.

For each individual, the age class estimate (see below for details) and dung size measurements were collected. To avoid double counting, identification techniques of individuals and family groups as described by Douglas-Hamilton (1973) and Moss (1983; 1996; 2001) were used. This mainly consisted using binoculars, to detect and note or make drawings for remarkable characteristics (such as hole or fold on the ear, tail cut or other distinctive and recognizable mark) and individuals in the groups. Notes and drawings mainly served as memories or identification keys in the field to avoid double counting of a given individual. Most of the observations were made near water points, where elephants concentrated during the hot periods of the day. A field team of two observers collected the data. Only isolated family groups or individuals were observed, counted and sexed; large groups that could not be accurately counted and sexed were not considered. To be precise, a total of 31 elephant groups were observed in the field. Groups sizes varied from 1 to 14 individuals. These groups consisted of either isolated families (consisting of adult females with their young; a rather unusual observation of a solitary female was also made); or a mixed group (including one or more families plus one or more adult males); or a set composed of one or more adult males.

The following data were recorded for all identified individuals/groups: GPS position, time (Ouagadougou standard time), number, age and sex of each individual, type of activity and dung size (= circumference) for each individual. Dung size was measured only for those excreta that were certainly attributable to a specific individual that was observed for a sufficient time to accurately determine its approximate age.

1.2.2 Sex determination

The difference in height, body fit, thickness of tusks, shape of head and external reproduction organs, as described by Moss (1996), were used for determining the sex of the observed individuals.

1.2.3 Age estimation techniques

At Nazinga, the precise date of birth of various elephant individuals were not known. Thus, it was impossible to determine the absolute age of individual animals from direct observations in the field. Because of the continuous growth of elephant all along his life (Laws 1966), it was possible to distinguish nine age categories of growth related to the population in the field (see below for details). The age category definition criteria rely on the general appearance of the individual, such as the body fit and size as well as the eruption of the defense. Absolute ages were then allocated to each defined category in place of relative ages that are indeed less useful (Laws 1966).

We assumed that, in the current years, the age of the oldest elephants in the West African savannah sub-region (including Nazinga) is probably reduced to half of that of the oldest African elephant known today from the field (i.e., 60-70 years, see Laws 1966). We then estimated an 'ecological' maximum age of the oldest elephant of Nazinga to be between 30 and 45 years. Based on the presumed age and the relative size of the largest individuals, we determined the absolute age classes that corresponded to the age categories of the elephants that were observed in the field.

The first four categories of young elephants were clearly identifiable in the field. Category I was made of the new-borns and infants of less than 1 year, characterized by their pinked colour and the capacity to walk under the belly of their respective mothers (Laws 1966). Category II (1-year-old individuals) included the infants that did not show these signs and that did not show any evident tusk tip; Category III (2-years-old infants) included those elephants having just the tip of their tusks visible; Category IV (3-years-old individuals) included all those elephants having their tusks clearly visible (5-7 cm) and with a height not higher than 150 cm.

The other five age categories were identified on morphological basis and height in relation to the largest adult of the group, using the same methodology as provided by Sukumar (1992) and Arivazhagan and Sukumar (2008) for Asian elephants but adapted to African elephants (Moss 1996): Category V (4- to 6-years-old; reaches mother's anal flap or above; tusks measuring 15-25 cm), Category VI (7- to 12-years-old; tusks above 30 cm, size over ¾ of the adult female height; males larger than females), Category VII (13- to 17-years-old; males reach same height as aged adult females), Category VIII (18- to 25-years-old; males are taller than all adult females, but their head is still relatively slender and more narrow than that of older males; in females the tusk base is distinctly bigger than in females of the previous category), and Category IX (more than 25 years old; males are very large and with massive head; females show thicker and longer tusks than in previous age categories). It should be however noticed that it was sometimes hard to distinguish the last three categories in the field.

1.2.4 Survey and measurement of dung-piles along line transects

Two dung-pile surveys were carried out: the first between 1st April and 6th May 2007 and the second between 5th April and 3rd May 2008. These periods were selected because they were sufficiently dry so that the dung decay would be very slow, thus facilitating our analyses and measurements. The measurements of dung-piles were carried out along line transects of 1 km each, distributed in a systematic-random manner over the study area (for more details of the survey design, see Hema et al. 2010a; 2010b). The observers walked slowly 'scanning' the ground on each side of the transect line; whenever a pile of dung was observed, they registered the stages of the dung-pile after Barnes et al. (1994) and measured the circumference of dung-piles. Only intact dung-piles close to the transect centreline were measured, so that we minimized the risk of bias that might occur in relation to visibility profile. For each measurable dung-pile, the circumference measurements were made on the three largest and intact boli. The arithmetic mean of these three boli circumferences was calculated and then considered in the analyses as the circumference of the whole dung-pile. Boli numbers were variable in the droppings, and we did not estimate any average number of boli per dropping.

To test the difference between fresh and dried dung-pile circumference measurements (using dung-shape classes as in Barnes & Jensen 1987), 50 dung-piles were subjected to measurements while fresh (Class A) and after they were dried (Class C). More in detail: Class A = fresh, moist, odorous, intact boli; Class B = intact, odourless, almost fresh boli; Class C = more than 50% of the boli were intact but dry; Class D = less than 50% of the boli were intact but dry; Class E = totally decomposed boli, pile of straw, dung turned into litter.

1.3. Statistical analyses

Age structures of the Nazinga elephant population was determined by their droppings. A study by direct observation method calculates theoretical values of frequency distributions which are compared with the observed values from dung-pile surveys results.

Generalized Linear Models (GLZs) were used to model the effect of the number of days occurred between the measurements of a same fresh and dry dung (Hosmer and Lemeshow 2000). In the model, the number of days between measurements was used as dependent variable and the identity link function and a Poisson distribution of error was used (McCullagh & Nelder 1989). The significant variables were computed using the best subset procedure using Statistica 6.0 software.

The relationship between elephant age and dung-pile circumference was tested by Pearson's correlation coefficient, using only the directly observed individuals. Then, we assessed the population's age structure similarity as resulted from direct observation and from the measurement of dung-piles by chi-square tests. More precisely, we determined the theoretical (or expected) size distribution by an individual recognition study through direct observation, which allowed collection of ages and sexes of individuals and groups of elephants coupled with their dung circumference measurements. This theoretical distribution was thereafter compared to the observed dung size distributions that resulted from the dung-pile surveys on line transects. The null hypothesis was that there should be no difference between the theoretical and observed distributions for a given season. If there is any statistical difference between the two distributions, then it would suggest that the dung measurement method is not applicable.

The statistical differences between the theoretical and the observed age structures (based on dung measurements) were assessed by G-test of independence adjusted by the Williams' correction (Sokal & Rohlf 2014).

All statistical analyses were made with PAST 3.0 statistical software; all tests were two-tailed and with alpha set at 5%.

2. RESULTS

2.1. Fresh versus dried dung-piles circumferences analysis

A total of 50 fresh dung-piles were encountered in the field along transects or on paths, were carried to the camp and dried to stage C. Out the 50 droppings, only 29 kept their intact form to further allow post-drying circumference measurements. The rest was destroyed by francolins (*Francolinus bicalcaratus*) and baboons (*Papio anubis*) who frequented the drying place. The number of days of drying varied from 3 to 22 days with an average of 11 days.

The results of the GLZ model revealed a significant effect of the number of days elapsed between measurements on the after-drying circumference of dungs (Estimate: -0.7252, SE: 0.3089, Wald: 5.511, p = 0.0189) but not on the circumference of wet dungs (Estimate: 0.39477, SE: 0.282, Wald: 1.959, p = 0.162). Thus, this model showed that an increase in the number of days elapsing between two measurements would be reflected into a decrease of the circumference of drying dungs, with the overall model explaining 70.72% of the total deviance (Intercept = Estimate: 20.5107, SE: 3.0905, Wald: 44.044, p < 0.0001).

2.2. Age structure

237 individual elephants were observed in the field, and they provided 320 dungs in total. However, for only 51 individuals it was possible to couple the dung circumference measurements with the age of the elephant producing it. In these individuals, there was a significantly positive relationship between the presumed age of elephants and the size of the dungs (r^2: 0.925, F: 605.27, n = 51, p< 0.0001; Figure 2).

The theoretical (expected) age structure, as appearing from the size classes of dung circumference, defined nine chronological age-classes of non-regular interval (Table 1), with 6% of individuals being less than 1 year old and the older age classes (Categories VII to IX) accounted for 35% of the whole population. A G-test of independence indicated that the frequency distribution of the droppings circumference categories was similar with that of the corresponding ages categories (G: 0.206, df: 1, p> 0.05; Figure 3).

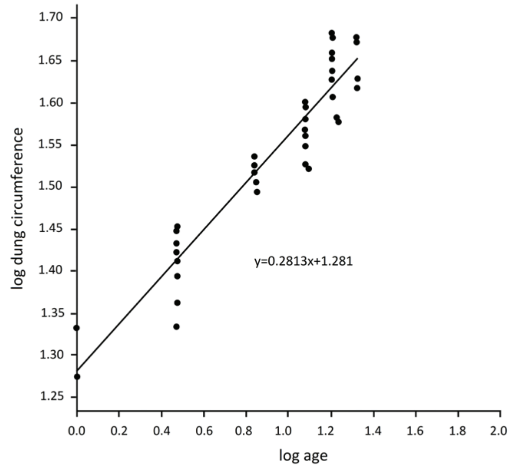

Figure 2. Relationship between presumed age and size (= circumference) of the dungs in directly observed elephants from Nazinga Game Ranch, Burkina Faso.

Table 1. Synoptic table for the theoretical (expected) age structure in the elephant population from Nazinga Game Ranch, Burkina Faso. Dung-pile circumference (cm) in relation to age class categories (I to IX) and in relation to the presumed age of individuals (Age Class, expressed as number of years) is given in this table.

Age Category	Dung-pile circumference class	Age class (year)	% of dungs
I	< 15	< 1	6
II	15-19	1	5
III	20-24	2	10
IV	25-29	3	9
V	30-34	4-6	16
VI	35-39	7-12	19
VII	40-44	13-17	22
VIII	45-49	18-25	13
IX	≥ 50	> 25	0

A total of 240 dung-piles of stage A and C was measured along transects in 2007 (24 of type A, 0 of type B, and 216 of type C), and 384 in 2008 (13 of type A, 11 of type B, 360 of type C). The transect surveys showed that 6% and 5% of dung-piles were attributable to Age Category I, for 2007 and 2008 respectively. The frequency distribution histograms for dung circumferences obtained for the two annual surveys are shown in Figure 4.

A *G*-test of difference between the medians of the frequency distribution of dropping circumferences obtained by direct observations, and those obtained during transects survey revealed consistent results between methods (G: 0, df: 1, P>0.05).

2.3. Sex structure

Out of the 237 animals observed directly in the field, there were 48 whose sex could not be determined. For the 189 sexed individuals, the male to female ratio for different age classes are shown in Table 2. Age specific sex-ratio estimates show almost equal sex ratio at 2 years and at 7-12 years old (Table 2), but the estimated sex ratio of the whole population was 1 male:2 females.

3. DISCUSSION

3.1. Methodological perspective

To our knowledge, the present study is the first field investigation of age and sex structures in a population of wild elephants in West African savannahs using the dung size measurements method. Therefore, it may highlight some remarkable methodological issues concerning its feasibility. Jachmann & Bell (1984) established, for the elephants of Kasungu National Park in Malawi, the same positive relationship between the dung-pile circumference and age class that was also highlighted by the present study. In addition, the relationships between elephant age and dung circumference classes at Nazinga Game Ranch was very similar to Malawi conspecifics (Jachmann & Bell 1984) when the elephant age was under 15 years. Beyond the age of 15 years, our measurements were relatively consistent with Jachmann & Bell's (1984) for males, but the female dungs were comparatively smaller in our studied sample, which slightly underestimates the age of the females. Overall, the similarities in the age structure patterns obtained by dung measurement analysis between Malawi and Burkina Faso elephants would indicate that the methodology may also work well in the West African savannah habitat. Therefore, the dung size measurement methodology should be privileged over alternative methods (direct sightings) because of its simplicity and low economic costs, which is well suited to the West African savannah countries in general.

However, our study pointed out the necessity of taking into consideration only the dungs with a similar condition for assessing age structures (i.e., only those in class A or only in class C), because of the effects that were highlighted by our GLZ analysis of the time interval between measurements on dung circumference.

Table 2. Sex-ratio of elephants in Nazinga Game Ranch, according to the various age classes.

Age class	Number observed	Number sexed	ratio M/F	Sex ratio
<1	12	6	2/4	0.5
1	11	3	1/2	0.5
2	22	14	7/7	1
3	23	11	4/7	0.6
04	40	30	12/18	0.7
07	46	42	20/22	0.9
13-17	54	54	14/40	0.4
18-25	28	28	8/20	0.4
>25	1	1	1/0	-
Total population	237	189	69/120	0.6

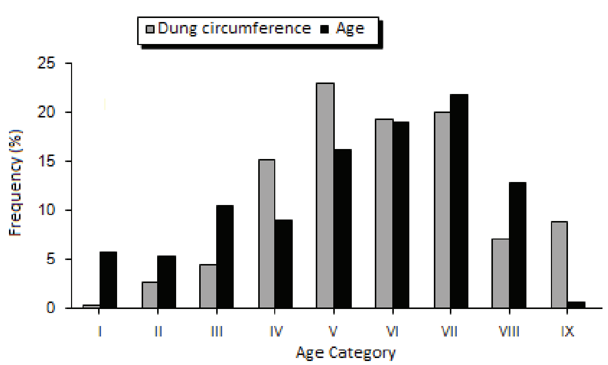

Figure 3. Frequency distribution of dung circumference categories and age of the directly observed elephants.

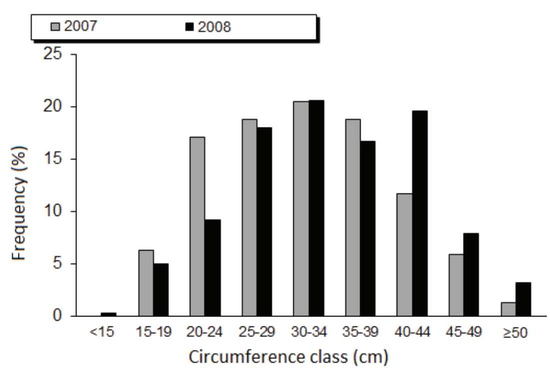

Figure 4. Nazinga elephants dung size frequency distribution derived from the dung size measurements (= circumference in cm) along transects in 2007 and 2008.

3.2. Age structure of Nazinga elephants

The Nazinga elephant population is as young as the ranch, and its main characteristic is the relative dominance of young/sub adult individuals; similar phenomenon has been observed in other African savannah elephant populations from elsewhere (e.g., Wittemyer et al. 2013 in Kenya), but contrary to this has been observed in Tanzania (Kioko et al. 2013). Indeed, in Nazinga, individuals under 15 years old seem to be the most abundant accounting for 77.1% of the total elephants by the dung-pile measurement method (Sebogo 1986) and for 79% by measurements of shoulder height through direct observation in the field (Damiba & Ables 1994). The same situation occurred in more recent years, as they accounted for 78% in 2008 (this study). However, while the 1994 and 2008 studies confirmed the preponderance of individuals less than 5 years old (they were estimated at 39% of the population in 2008), the 1986 study found that this fraction of the population was between 16% and 18% (Sebogo 1986). Individuals younger than 1 year and individuals aged 1-2 years were very few in the population. The constant growth in the size of the elephant population since the creation of the ranch in 1979 (when 40 elephants were present in the ranch, whereas about 300 were present in 1982 and about 400 in the early 1990s; Hema 2012) does not appear to be coupled with an increase in the proportion of immatures. Instead, this supports the idea that the increase in the population size is strongly related to migration patterns over the years from neighbouring and less secured parks including the Kaboré Tambi National Park and the Sissili forest reserve.

Age structures skewed in favour of sub-adults support that the elephant population is recovering from past heavy poaching pressure. The age structures were indicative of high levels of recruitment. Though little mortality was observed during the study period at Nazinga (Hema 2012), the population might suffer poaching pressure during the wet season, when they disperse and migrate outside Nazinga and along less secured corridors in the south-west (Sissili Forest Reserve in Burkina Faso) or in the north (Kabore-Tambi National Park, Burkina Faso). The low representation of calves in the dung-pile population was probably influenced by three factors: (i) the low visibility of small dungs; (ii) the fact that these droppings are more vulnerable to degradation processes; and (iii) the fact that calves are breastfed by their mothers, thus, likely to spend relatively less time grazing (with a consequent daily production rate of small droppings that should be less than that of adults) (Jachmann & Bell 1984).

One may expect that infants show different defecation rates with other animals of different ages (Coe 1974; Jachmann & Bell 1984). The proportion of infants (< 1 year old) might have been probably underestimated because of their lower defecation rate, and because their small boli could disintegrate more rapidly (Jachmann & Bell 1984). Also, defecation rates do vary seasonally in more open habitats because of the large seasonal variations in moisture, lignin and protein in the food (Guy 1975; Barnes 1982). Seasonal variation in dung decay rates has been described in forest areas (White 1995; Barnes et al. 1997).

3.3. Sex-ratio structure of Nazinga elephants

The sex ratio structure of Nazinga elephants was skewed towards females. Female-biased sex-ratios in elephants are usually due to overhunting of adult males for the tusks ivory (Kioko et al. 2013; Wittemyer et al. 2013). Thus, the observed sex ratio may indicate that the Nazinga population had not yet fully recovered from past poaching pressures and may be subject to a current level of poaching, sufficient to maintain the skew.

During our study, we did not see any infant mortality; it seems that with the globally acceptable habitat conditions, infant mortality is reduced. This supports the good population expansion in the ecological complex of Nazinga-Sissili-Parc National Kaboré Tambi, if the conditions of security and food availability (mainly water) were improved in these areas.

In interpreting our results, we should also consider the shortcomings of our study. First of all, for performing our study, we had to assume an 'ecological' maximum age of the oldest elephants. Hence, future research should gather data on the births of several individuals in order to validate our estimations of age for Nazinga Game Ranch, and possibly for other West African populations of elephants as well.

In the dry season, the rate of decay is low, or perhaps zero, while animals continue to defecate. Therefore, there will be a gradual accumulation of dung during the dry season (Jachmann & Bell 1984). At the end of the wet season, the dung density will be low because the rate of decay is rapid. It becomes necessary to give an estimate of the accumulation of droppings over the dry season. Dung pile accumulation rate is quite important during dry seasons. To improve the estimates, the dung-pile accumulation rate during dry season in savannah must be evaluated. Factors that favour the accumulation should be better identified and a model explaining the accumulation should be built.

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