FIELD NOTES

Using dung bolus diameter for age estimation in an unstudied elephant population in Udzungwa Mountains, Tanzania

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Abstract

Savannah elephants make extensive use of montane forest in three Tanzanian massifs, including the highly biodiverse Udzungwa Mountains. We have begun the first study of the Udzungwa elephant population, which is perceived to be increasing and is compressed due to loss of connectivity with adjacent protected areas. Meanwhile, human-elephant conflict outside the forests is escalating. We tested a non-invasive technique for estimating elephant age from dung bolus diameter using a predictive equation derived from known-age elephants in Amboseli National Park, Kenya. Our results from 137 measurements of intact boli found an overall mean dung bolus diameter of 11.0 cm ± 2.1 and a mean age of 16.0 years ± 5.6, suggesting that the Udzungwa population is young but contains reproductive-age adults (>10 yrs old). This method's precision and accuracy require further testing and we discuss the limitations; however, it has potential as a monitoring tool for elephant populations inhabiting forest elsewhere in Tanzania, and across Africa. We intend to re-run this analysis using a larger sample size from more sites, as well as incorporate elephant monitoring into the Udzungwa Mountains National Park's long-term management plan.

Key words: dung bolus diameter, demography, forest-dwelling savannah elephants, Udzungwa.

Résumé

Les éléphants de savane font un usage étendu de la forêt de montagne dans trois massifs tanzaniens, y compris les Monts Udzungwa à très haute biodiversité. Nous avons commencé la première étude de la population d'éléphants d'Udzungwa, qu'on perçoit être en croissance et concentrée à cause de la perte de connectivité avec les aires protégées adjacentes. Dans l'entre-temps, le conflit homme-éléphant à l'extérieur des forêts s'aggrave. Nous avons testé une technique non envahissante pour estimer l'âge des éléphants à partir du diamètre de la boule de crotte en utilisant une équation de prévision dérivée des éléphants ayant un âge connu dans le Parc National d'Amboseli au Kenya. Nos résultats de 137 mesures de boules intactes ont trouvé une

moyenne générale du diamètre de la boule de crotte de 11,0cm ± 2,1 et un âge moyen de 16 ans ± 5,6 ce qui suggère que la population d'Udzungwa est jeune mais renferme des adultes à l'âge de reproduction (> 10 ans). La précision et l'exactitude de cette méthode exigent davantage d'essais et nous discutons les limitations; cependant, elle a la possibilité d'être un outil de suivi pour les populations d'éléphants qui habitent la forêt ailleurs en Tanzanie, et à travers l'Afrique. Nous projetons de refaire cette analyse en utilisant un échantillon plus large provenant d'un plus grand nombre de sites, ainsi que d'incorporer le suivi de l'éléphant dans le plan de gestion à long terme du Parc National des Monts Udzungwa.

Introduction

Assessing demographic structure is important for managing and conserving elephant populations. Addressing this objective is particularly challenging in forest habitats, where animals cannot be easily or safely observed. Of the various techniques developed for non-invasive age estimation, the use of dung bolus diameter is arguably the most promising (Jachmann and Bell 1984; Reilly 2002; Morgan and Lee 2003; Morrison et al. 2005). Using dung bolus diameter is simple, low-cost and has great potential for ranger-led studies of elephants in closed habitats, such as populations of the highly threatened forest elephant *Loxodonta africana cyclotis* (Blake et al. 2008). To date, however, this method has been used to assess demography in a small number of sites, and has only been attempted in a single forest site (Morgan and Lee 2003). Our aim is to test this technique on a previously unstudied population of savannah elephants (*L. a. africana*) inhabiting forest in the Udzungwa Mountains, Tanzania. We estimated age from dung bolus diameter using an equation relating known age to dung size for the savannah elephants of Amboseli National Park, Kenya (Morrison et al. 2005). Bolus size distributions may be population-specific (Morgan and Lee 2003) but if asymptotic and lower dung diameters are comparable, then growth equations derived from one population can be applied to age another when calibration of the relationship with independent estimates of age may be too costly or not feasible. This method has considerable potential as a conservation research tool for forest elephant populations across Africa, but its precision and accuracy need further testing.

Methods

Study area

Dung surveys were conducted at three sites in Mwanihana Forest (179 km^2, centred at 7 46'S, 36 51'E) within the Udzungwa Mountains National Park (UMNP), which covers 1990 km^2 in south-central Tanzania (Fig. 1). The Udzungwa Mountains (250–2600 masl) cover 10,000 km^2 and comprise a mosaic of forest, woodland, bush and montane grassland, and are the largest and most diverse block of the Eastern Arc Mountains,

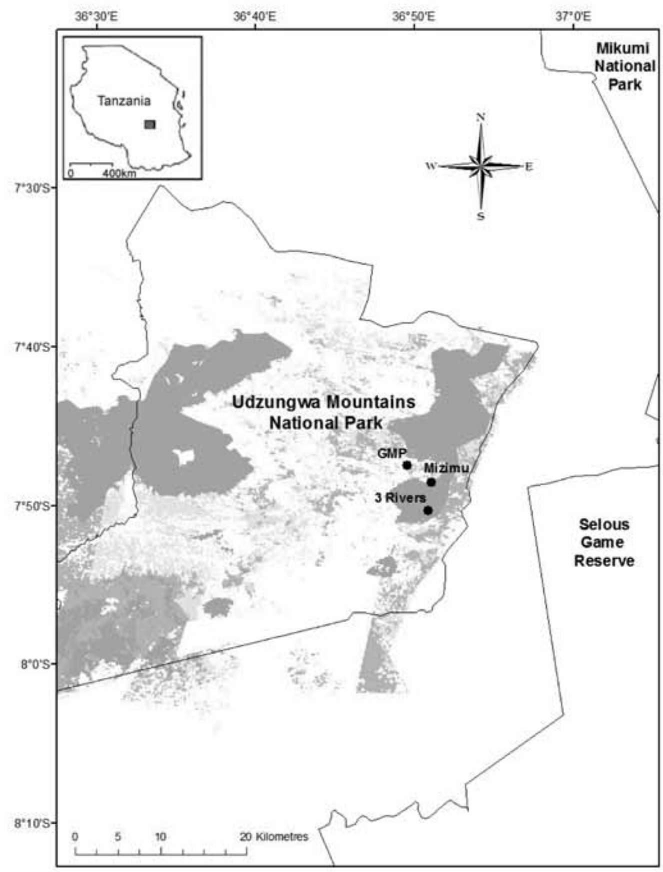

Figure 1. Three sites of dung surveys in Mwanihana, UMNP, Tanzania.

a recognized biodiversity hotspot and centre of high endemism (Myers et al. 2000; Burgess et al. 2007). Mwanihana Forest lies on the slope of the east-facing escarpment ranging from 300 to 2100 m. Mean annual rainfall is up to 2500 mm and falls mostly during two wet periods—the short rains (November–December) and the long rains (March–May)—which are interposed by a hot and relatively dry period (January–February) and an extended dry season (June–October).

Three sites in Mwanihana Forest were surveyed: (i) Three Rivers: primary, high-canopy sub-montane forest with an open understorey (1000–1500 masl); (ii) Mizimu: a mosaic of primary sub-montane and riverine forest, dry woodland and grassland with a dense herbaceous and woody shrub understorey (600–1100 masl); (iii) GMP: open to semi-wooded grassland at the forest edge with riverine, monospecific patches of *Aframomum* sp. (900–1200 m).

The elephant population of the Udzungwa Mountains has not yet been studied and the forested areas are only mapped as 'possible' range on the African Elephant Database web site (Blanc et al. 2007). This is the only site in the Eastern Arc Mountains supporting resident elephants. Recent assessments of corridor areas outside Udzungwa NP have documented connectivity of elephant populations between the Udzungwa Mountains and the Selous Game Reserve and Ruaha National Park (Jones et al. 2009).

Survey methods

We used a recce-survey method which entailed walking 3-km triangular transects (each side of triangle equalling 1 km) in each direction from camp (north, east, south and west) over a period of 4–6 days, giving a total of 12 km of transects walked per site. All transects were followed using a compass and hip-chain thread to measure ground distance walked with a maximum strip-width of 15 m. Transects were conducted between December 2008 and February 2009. We used callipers to measure the long and short axes of all intact boli detected along transects, following recent work in Amboseli National Park, Kenya (Morrison et al. 2005) (Fig. 2). Diameter was equal to the mean of the two axes. Dung pile age was estimated on the basis of local experience and monitoring of dung decay in >100 marked piles (Jones and Nowak, unpublished data). Those boli believed to be older than six months or decomposed were not measured. Intact boli were defined as those with no deformations owing to impact with the ground or evident decay over time.

Data analysis

Elephants can live for over 60 years, but the data from Amboseli (Morrison et al. 2005) suggest that age will only reliably predict bolus diameter up to 20 years in females and 25 years in males. This is a typical problem with asymptotic growth curves, which lose precision and accuracy as the slope begins to decrease with age (Shrader et al. 2006).

We used our measures of dung bolus diameter to predict age using Amboseli's von Bertalanffy's growth equation, which models the growth relationship of dung diameter with known age (Morrison et al. 2005). Males grow faster and for a longer time than do females (Lee and Moss 1995; Shrader et al. 2006), and have a larger bolus for age (Jachmann and Bell 1984). We were unable to assign sex to dung piles in this sample, while Morrison et al. (2005) used dung diameter from individuals of both known sex and age, and fit separate curves for each sex. We therefore fit two models to the same set of data: one for males and one for females up to a bolus size of 14 cm, after which individuals were classed as male. We used 14 cm as a cut-off as this was

Figure 2. Using calipers to measure the axes of a round dung bolus.

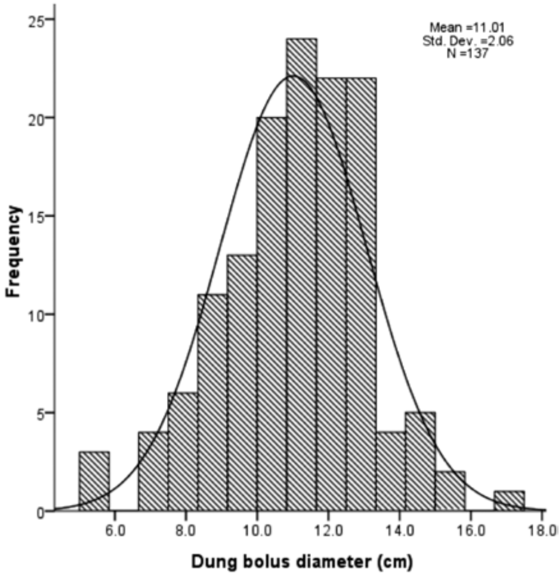

Figure 3. Frequency distribution of dung bolus diameter.

the size at which males and females in the Amboseli sample clearly separated. We fit the models using five randomizations to assign sex to each sample, and then determined the 50% distribution of males and females so as to predict age from the sex-specific equations. Results would, however, be more accurate if 95% confidence intervals could be modelled with further bootstrap estimators, but confidence limits were not provided in the original model (Morrison et al. 2005) and further randomization by sex would require a larger sample than the 137 here.

Results

A total of 137 intact boli from 689 piles were measured (41.6% of 214 piles in Three Rivers; 8.5% of 294 in Mizimu; 13.3% of 181 in GMP). This sample size of intact boli is comparable to that of Morgan and Lee (2003). Boli came from piles estimated to be 2–6 months old with a mean dung age of 3.3 ± 1.6 SD months. The mean number of boli in a pile was 5.38 ± 2.2. An additional second intact bolus was measured in 15 of 137 piles.

The overall mean dung bolus diameter was 11.0 ± 2.1 cm with a range of 5.45–17.2 cm (Fig. 3). No significant difference in mean bolus diameter was found between survey sites (ANOVA, $F_{2, 136} = 2.65$, $P = 0.074$) although a broader distribution and therefore age range was found in GMP by comparison to Mizimu and Three Rivers (Fig. 4).

The mean difference between boli from the same pile was 0.69 cm ± 0.7 SD (compared with 0.33 cm ± 0.13 SD in Amboseli, Morrison et al. 2005) but this difference was not significant (paired samples t-test, $t = 0.38$, $df = 14$, $P = 0.71$) and the two means were highly correlated ($r = 0.89$, $P < 0.001$).

Our results based on dung (Fig. 5) suggest that the population using the area is relatively young, but does contain reproductive-age adults (>10 years). The largest bolus diameter was 17.2 cm compared with 18.0 cm in Amboseli and 18.5 cm in Kasungu National Park, Malawi. The >17.0 cm bolus suggests the presence of at least one prime old male. Our minimum bolus of 5.45 cm was between Amboseli (4.75 cm) and Kasungu (6 cm) and, as expected, was larger than that found for forest elephants in Petit Loango (4 cm) (Morrison et al. 2005; Jachmann and Bell 1984; Morgan and Lee 2003, respectively).

Discussion

The use of dung diameter to predict age and therefore model populations appears to yield promising results. The frequency distribution of dung diameter is similar to that found for forest elephants in Petit Loango (Morgan and Lee 2003). Age structure in the Udzungwa Mountains, as estimated here, ranged from 5–40 years and included young and prime aged individuals, although the population is far younger, with an average age of 16, than that of the Amboseli population (Moss 2001).

Using both old and fresh dung increases the probability of re-sampling individuals who range consistently through the transect areas. Intact dung does not usually persist long in this environment due to dung predators, rainfall, trampling and breaking up by seed eaters. We did find intact dung that was aged at six months, while most was aged at three to four months (Barnes and Jensen 1987), which is unsurprising given that most sampling was carried out in the dry season of a particularly dry year.

We have assumed that re-sampling was homogenous across ages and/or age classes. Defecation rates can differ between individuals such that re-sampling may be biased towards older individuals that have more fibre in the diet than suckling infants. Furthermore, tiny faecal samples are unlikely to persist and young calves under one year old will be under-represented (Jachmann and Bell 1984).

It is worth noting that the error involved in attempts to use such curve-fit processes in order to predict the independent, as opposed to the dependent, variable can be considerable. The initial iteration process assumes that bolus size is predicted by age, and thus the constants converge to maximize the fit with observed age. Using the equations to predict age from bolus size does not allow for convergence around an age of maximum likelihood or best fit for growth constants. Thus, for example, the smallest boli of 5–6 cm, which would represent a calf under two in Amboseli, is here predicted to be 5 years old. While age is predicted with precision, the variance in the initial curve fitting process will create problems of accuracy, specifically at the start of a von Bertalanffy curve, where minimum ages are negative. Attempts to fit an unknown age to a known bolus diameter requires the confidence intervals of the original models and further tests from other populations to assess expected distributions.

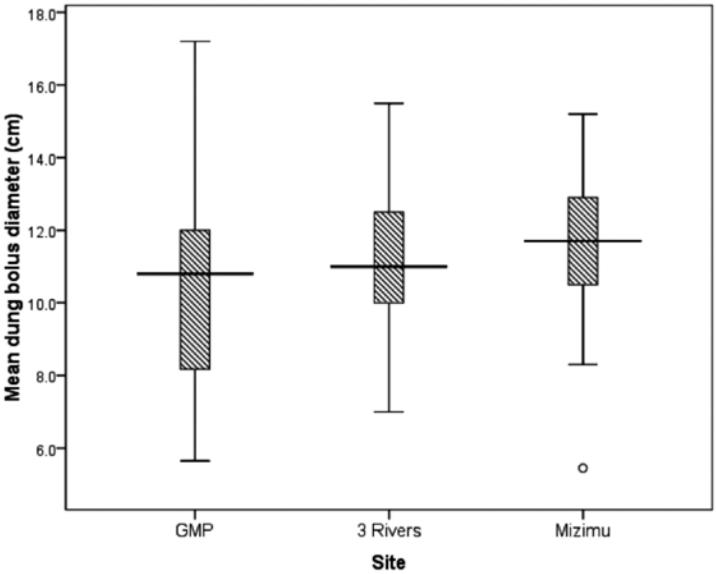

Figure 4. Mean dung bolus diameter by survey site where n = 23, 89, 25 for GMP, 3 Rivers, and Mizimu respectively. The outlier in Mizimu was a bolus of 5.45 cm diameter.

Our age distribution from dung diameter suggested a young population. An alternative explanation, although further sampling would be required, is that these elephants are relatively smaller than those of Amboseli and Kasungu. Given the relatively small size of elephants in the adjacent projected area of Mikumi NP (pers. comm. Lee 2006), this might be a possibility, but as a bolus size range equal to that of Amboseli was observed, it seems unlikely. The young ages could be a result of small sample sizes and unknown sexes, or of the error inherent in using a von Bertalanffy growth equation with relatively few samples.

Future directions

Genotyping would greatly complement this study in assessing the extent of individual re-sampling. We will continue sampling in the wider Udzungwa area to increase our sample size and also to ensure that axes measurements of intact boli do not change with decay. While the Udzungwas may be a suitable refugium for a small population of elephants, human-elephant conflict is escalating and historic migration routes are being lost due to rapid land use change (Jones et al. 2009). We plan to incorporate demographic monitoring of this population into the long-term management strategy for the region.

This technique offers a potentially affordable and rapid way for rangers and managers to monitor demographic changes in elephant populations. We recommend that this method be repeated at other sites to further test its applicability—especially for forest elephant populations—ideally when independent data on age are available for calibration. Understanding the responses of elephants to anthropogenic pressures and other stressors, as reflected by changes in their age structure, is vital to ensuring their future.

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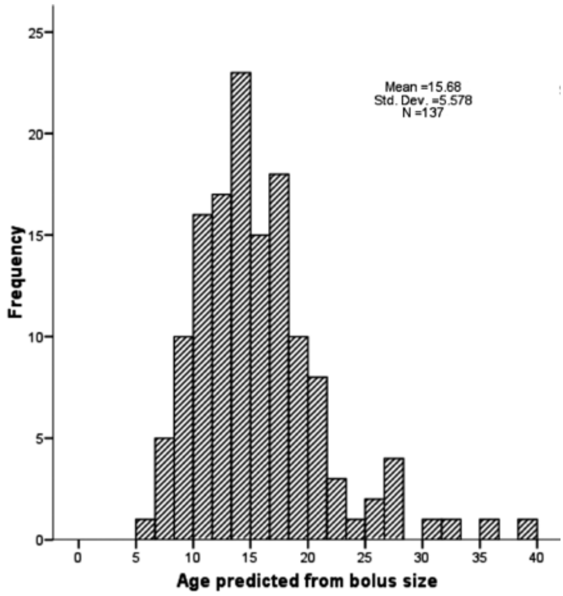

Figure 5. Preliminary population age structure in Udzungwa Mountains National Park based on randomization of assignment of sex to boli, using Morrison et al. (2005) Amboseli growth curves; males: asymptote L_{asy} = 16.433, growth constant K of 0.093, and a start age of -4.909 years; females asymptote L_{asy} = 14.354, growth constant K of 0.158, and a start age of -2.722 years.

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