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Environmental Correlates of African Elephant (*Loxodonta africana*) Distribution in Manyara Area, Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author JK designed the study and assisted in all other aspects of the study. Author VTH and MMW did fieldwork and draft write up. Authors DM and YK assisted in reviewing the paper. Author CK assisted in data analyses. All authors read and approved the final manuscript.

Original Research Article	

ABSTRACT

African elephants are a dominant feature of the African Savannah. Their numbers are however declining, partly due to habitat alteration and loss. Understanding how elephants respond to environmental variables and anthropogenic activities is necessary in conserving elephant habitats. This has become imperative in human dominated rangelands such as the Tarangire Manyara Ecosystem (TME). We present a baseline survey on the effects of formal protection, presence of agriculture, roads, urban areas and specific habitat characteristics (surface water presence, tree density, vegetation cover and habitat type) on elephant distribution (indicated by elephant dung) in Manyara Ranch (MR), Lake Manyara National Park (LMNP) and the adjacent community area (CA). We supplemented the dung survey with opportunistic direct elephant sightings. Twenty six elephant groups were identified within the study area. Elephant dung density was higher within protected areas than in the CA. Elephants largely avoided farmland and urban areas but not main

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roads. Elephant dung density was positively related to tree density and habitat cover but not tree height. There was differential distribution of bull and family elephant groups from fresh surface water points. The family groups remained in closer proximity to fresh surface water than male groups, and family groups avoided areas with high poaching pressure. Results suggest that protection of suitable habitat, strategic water provision, law-enforcement and wildlife friendly land-use planning is key for the future of elephants in TME. We propose Community Based Conservation (CBS) mechanisms that engage local people and village governments to ensure that elephants are able to move between protected areas. We recommend consistent monitoring of elephant movement and habitat use outside protected areas in the TME.

1. INTRODUCTION

Environmental factors, both abiotic and biotic, influence habitat quality and quantity and thus wildlife distributions across landscapes [1-4]. At the same time, human activities and infrastructure may affect behavior of wildlife species [5-6]. This is particularly the case for elephants which prefer habitats with quality forage, cover and surface and water availability [2-5]. Elephants have a large home range, but largely avoid agricultural and urbanized areas outside protected areas [7-8]. The presence of human activities and infrastructure may either impose greater risks to elephants when coming into contact with humans, physically alter elephant habitat, or block their movement paths [8-9]. In response to such anthropogenic alterations of the landscape, elephants may alter their ranging behavior to avoid risk imposed by humans and retreat to safer areas, such as protected areas [10] and may venture in human dominated areas at night only [11].

In the Tarangire Manyara ecosystem of Tanzania (hereafter TME, agriculture increased five-fold from 1984 to 2000) [12]. This land-use change may expose elephants to elevated rates of conflict with farmers and may physically constrict and block elephant movement if these land-use changes are located within existing corridors [2]. In addition to agricultural expansion, TME has experienced substantial infrastructural development. Of significance is the tarred highway that links North Eastern and North Western Tanzania. The road borders several protected areas in the ecosystem and thus may have negative effects on elephant movement in the area. In addition, tourism activities and agriculture have resulted in development of a peri-urban center (MtowaMbu) in the area. While agriculture, urban areas and areas near major roads can provide habitat for certain wildlife

species, they have been shown to exclude others [7]. While previous research provide evidence for long-distance movements of elephants between protected areas within TME [2], it is poorly understood how different spatial variables affect the movement and overall distribution of elephants in this ecosystem. Given that such knowledge is needed in making informed conservation initiatives such as the delineation of elephant corridors [13] we embarked on a study to identify factors influencing elephant distribution in TME. This enhances the understanding of how ecological and human factors influence elephant spatial use of a highly variable landscape. Based on previous factors known to affect elephant distribution [3,5,8,10], we hypothesized that protection status of an area; presence/proximity to agriculture, roads, and urban areas; and habitat characteristics (surface water presence, tree density, vegetation cover and habitat type) would influence the distribution of elephants.

2. MATERIALS AND METHODS

2.1 Study Area

The Manyara area (1213 km^2) lies on the eastern rift valley (35°86', 3°.31' NW and 35°72', 3°71'SW) and is bordered by the Makuyuni-Babati road (36°10' 3°55' E, 35°99', 3°65'). It comprises of two protected areas, Lake Manyara National Park (hereafter LMNP, 645 km^2 in extent), and Manyara Ranch (hereafter MR, 182 km^2 in extent), as well as a game controlled area that is heavily utilized by local communities for farming, settlements and pastoralism (hereafter CA) (Fig. 1). The entire study area is part of the TME that comprises about 20,000 to 35,000 km^2 [14].

TME has an arid to semi-arid climate, with marginal agricultural potential. It receives a mean annual rainfall of 869.4 mm, with precipitation

occurring in two rainy seasons: long rains (March to May) and short rains (November to December) [15]. The vegetation is dominated by Acacia-Commifora bushland and alkaline lake grassland. However, in LMNP localized effects of springs and streams sustain groundwater forests [16]. The Rift Valley escarpment contains unique vegetation communities characterized by *Terminalia brownii* and *Croton megalocarpus.* The TME has an overall elephant population of about 2,561 elephants [17]. It is estimated that there are about 200 elephants in LMNP [18], 2334 in Tarangire National Park [19] and over 50 in MR [18]. There are however, seasonal variations in elephant density in the two areas.

Apart from elephants, plains game such as Maasai giraffe (*Giraffa camelopardalis tippelskirchi*), gazelles (*Gazella* spp.), common wildebeest *(Connochaetes taurinus albojubatus*), impala (*Aepyceros melampus*) and plains zebra (*Equus burchellii*) occur in the area. We focused our field work on three areas with different management regime. LMNP is used for photographic tourism, research, and biodiversity conservation whilst MR is used for livestock breeding, wildlife conservation, and tourism. The CA between the LMNP and MR has experienced increased agriculture and human settlement in the last 30 years [12]. To the north of LMNP, irrigated farmlands are located, while patches of rain-fed agriculture occur within the CA. The plains between MR and CA are mainly used for livestock-keeping by the Maasai people.

2.2 Data Collection

Field work was conducted within LMNP, MR and CA for a period of nine consecutive days in November 2012. Because direct and diurnal observations of elephants may provide only limited information on their space use, we mainly focused on assessing elephant dung in the ecosystem, an often used proxy for estimating density and distribution of elephants [20]. Forty five transects, established along major and minor roads were used to collect data on number of elephant dung piles and habitat characteristics. Transects of 500 m at 250 m intervals were used. Along transects, quadrat plots of 20m*20m were established. In each plot, the number of elephant dung piles, the habitat and vegetation cover type, and number of woody plants (shrubs and trees taller than 1m) and plant height were determined.

Habitat classification was based on physiognomic structure [21], and simplified into bushland, shrubland and grassland. Mean tree height was visually estimated by the researchers. The vegetation cover was classified as sparse (plant spread out), open (plants close together) or closed (visibility poor through the plants). The location of each plot was recorded using GPS handhelds (Garmin GPSmap 76Cx) and mapped using a Geographical Information System (GIS, Arcview 3.1). Using the nearest neighbor function, the distance between sampling quadrats and the nearest fresh water point was measured. To complement the indirect assessment of elephants, we also recorded direct elephant sightings along transects. When elephant(s) were sighted, information on elephant group size and type, age, sex and location were recorded. The elephant group type and sex of individuals were determined based on morphological features [22].

To determine elephant use of surface water points containing fresh water, all the fresh water points along the roads were mapped. Any time elephants were sighted, the distance to the nearest fresh water point was determined directly from the GPS. In order to assess elephant habitat and vegetation cover preference in relation to its availability, the Ivelev's selectivity index (E) was used [23]: $E = (r_i-p_i)/(r_i+p_i)$, where, E = measure of selection or preference, r_i = proportion of habitat $type_i$ used and p_i = proportion of habitat type available. Regression and correlation analyses were used to determine relationships between tree density, tree height, proximity to fresh water and elephant dung density. Chi-square goodness of fit test was used to test differences elephant sex ratios between areas. Kruskal-Wallis tests were used to test if for elephant dung in density differed between LMNP, MR and CA.

3. RESULTS

3.1 Effects of Human Activities on Elephant Numbers and Distribution

Twenty-six different elephant groups were observed in the study area over a period of nine days. Eight groups were seen in MR and 18 groups in LMNP. No elephants were seen in the CA, while a total of 158 individual elephants were recorded in LMNP and MR. Elephant dung density (piles/km^2) was 459.45±116.85SE in LMNP, 276.63±51.73SE in MR and 12.35±5.00SE in the CA. A Kruskal Wallis test

suggested that dung density differed significantly across the three sites (χ^2 = 53.46, d.f.=2, p<.05).The presence of Arusha-Karatu highway did not seem to affect the elephant distribution; both family and all-male groups were frequently seen within 30m of the main road during this study (Fig. 1). In contrast, elephants were never seen closer than 2.5 km from the nearest urban areas. The nearest distance between directly observed MR and LMNP elephant clusters was 22.35 km, suggesting a relatively large spatial gap between elephants using the two protected areas.

3.2 Gender Specific Range use by Elephants

There was a significant difference between male and female elephant ratio among the twenty six elephant groups seen in MR and LMNP (χ^2= 55.90, d.f. =1, p<.001). In the Ranch, the ratio was 7:1 compared to a ratio of 0.4:1 males to females in the Park.

3.3 Effect of Fresh Surface Water on Elephant Distribution

The average distance between fresh surface water and elephants was .50 km $\pm$ .12SE. Family groups stayed on average .25±0.04SE km from fresh surface water points compared to an average distance of 1.56 km $\pm$0.16SE between the male groups and accessible fresh surface water. There was a negative and significant relationship between elephant dung density (log x+1 transformed) and distance to fresh surface water points dung (r=-.387, p≤.001) (Fig. 2).

3.4 Effect of Habitat Characteristics on Elephant Distribution

Based on dung density, elephants preferred bushland (E = .22) and avoided grassland (E = -.47) and shrubland (E = -.49). Elephants preferred closed habitats (E = .48) over open (E = -.29) and sparse (E = -.53) habitats. There was a significant and positive correlation between tree density and elephant dung density (r=.685, p<.001; Fig. 3). There was also a weak but significant correlation between elephant dung density and tree height in the CA (r = .216, p = .042). There was no correlation between elephant dung density and tree height in both LMNP and MR (p>.05).
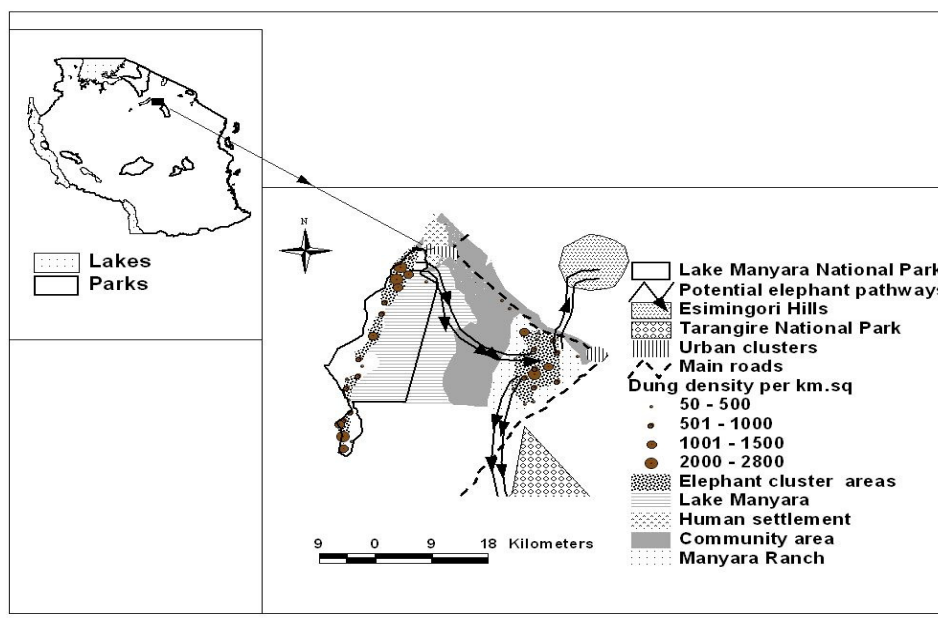

Fig. 1. Elephant distribution based on dung density survey conducted in November 2012 within the Lake Manyara area of northern Tanzania. The connected lines and arrows indicate potential migration routes between protected areas
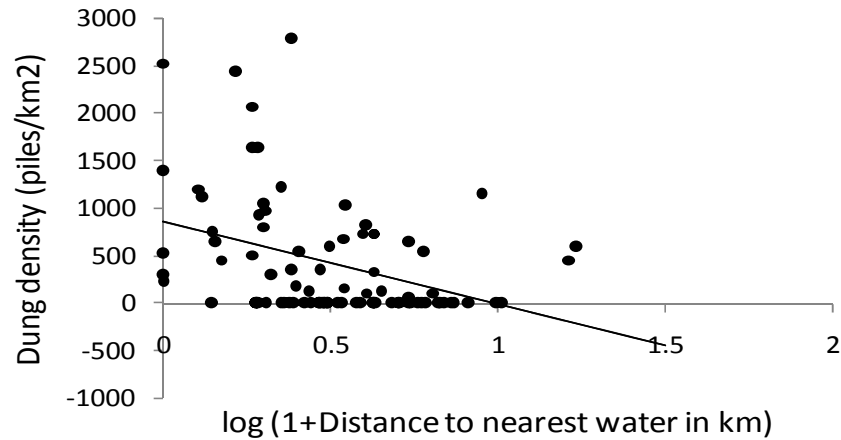
Fig. 2. Relationship between elephant dung density and distance from fresh surface water (log x+1 transformed) in the Tarangire-Manyara ecosystem, Tanzania. A linear model describes the relationship as: y=855.4-861.5x ($F_{1,85}$= 13.79, p≤.001, R^2=.13)
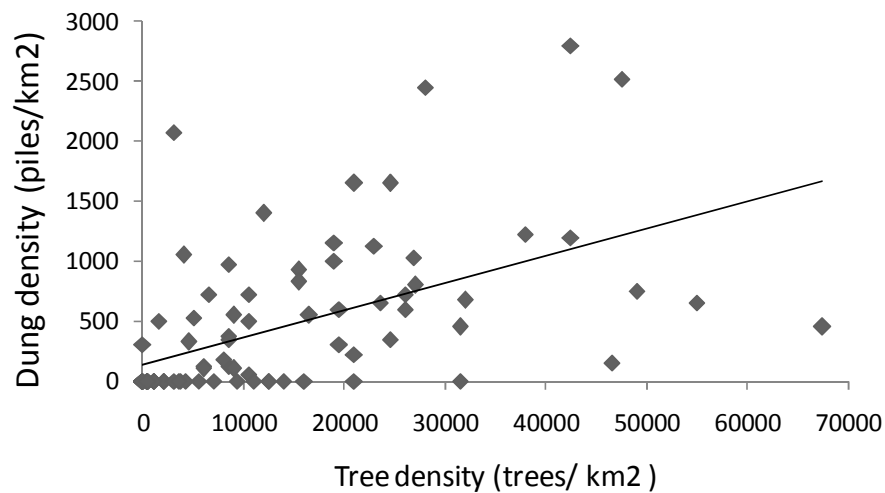

Fig. 3. Relationship between plant density and elephant dung density in the Tarangire-Manyara ecosystem, Tanzania. A linear model describes the relationship as: y=137.1-.02x ($F_{1,89}$=36.16, p≤.001, R^2=.29)

4. DISCUSSION

Elephants are still relatively widely distributed within the Manyara area of the TME. Manyara Ranch has become an important elephant habitat. Before MR was established as a conservation area under the Tanzania Land Conservation Trust, elephants did not regularly utilize this area [19]. The recently observed elephant high use of MR suggests that elephants can establish themselves in areas outside core protected areas if they deem such areas safe. Since 2003, frequent anti-poaching controls take place in the area. The low elephant density in the

CA (no direct sightings and low dung density) suggests that elephants largely avoid this human dominated area. Multiple underlying reasons may explain this phenomenon. First, surface water in the CA is limited and elephants have been shown to be very water dependent. Secondly, the woody vegetation in the CA is highly degraded due to unsustainable harvesting e.g. for fire wood and housing. Thirdly, elephants may avoid the CA because they may encounter humans who may harass or even kill them.

Even the minimal elephant utilization of the CA often leads to severe human-elephant conflict

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situations. Agricultural areas, apart from possibly physically displacing wildlife, are potential ecological traps for wildlife [24] due to arising conflicts between humans and wildlife. For instance, in May 2012, three elephant bulls were eliminated by the Tanzania National Park's Authority Problem Animal Control Unit after being trapped in the farmlands adjacent to LMNP. Such risk taking behavior seems to be particularly exhibited in male elephants [25]. This may also explain why family but not male elephant groups largely avoided MR.

While anti-poaching patrols are in place in MR, there is intermittent elephant poaching [19]. The family groups with young elephants are less risk-taking, often staying in safe and resource-rich areas, and rarely staying more than 10 km away from fresh surface water sources [8]. In addition, the presence of young may have limited the extent the family groups stay away from the fresh surface water points. In this study, male elephants stayed up to 1.5 km from perennial surface water points, with young-adult and female groups staying only up to 0.5 km from fresh surface water points. In LMNP, rivers and streams fed by aquifers from the Rift Valley escarpment provide an all season fresh water source. In the CA, the few perennial fresh water sources have been taken up by irrigated agriculture or are heavily utilized by livestock. In MR, two semi-permanent water dams are the only available water in the dry season. This may limit elephant use of both MR and CA.

Our results underline previous finding that elephants typically avoid areas dominated by human activity or may only visit those areas at night [11,25]. Elephants are long-lived and have a high cognitive ability, allowing them to adapt space-use patterns based on past experiences [26]. As we still found dung outside protected areas, elephants were apparently still able to move between protected areas. However, habitat fragmentation associated with expansion of urban areas increasing crop farming and high extraction of wood is serious threats to elephant habitat, connectivity in TME. There is thus immediate need for wildlife managers and land-use planners in the area to develop strategies to mitigate the cumulative effects of development on wildlife populations [27].

Lake Manyara National Park appears to be a major stronghold for elephant conservation in the ecosystem. The park has varied habitats due to a

range of ecological conditions including soil chemical composition [28], local microclimatic factors such as soil moisture, high grazing pressure along the lake (Kioko pers. obs. 2013), wildlife population fluctuations, and a history of fire suppression [29]. This has created a mosaic of habitats within the park. Elephants make top-down foraging decisions by first selecting landscapes, then habitats within those landscapes [30]. Within habitats, they select fine scale habitat features such as habitat cover and specific plant species.

In the TME, elephants preferred closed bushland over shrubland and grassland; and closed over open vegetation cover type. The benefits for utilizing closed habitat are apparently greater as most closed habitats, such as woodland, tend to be more diverse, productive and often associated with water availability [8]. Similarly, this finding is underscored by the positive correlation between tree density and elephant dung density which may indicate that elephants benefit from improved cover and forage [31]. Habitat use may however, vary seasonally [32]. During the early dry season, elephants have a higher intake of grass, but relocate to feed more on woody plants as the dry season progresses. The quality of grassland within the study area has however been compromised by increased livestock and wildlife grazing. For instance, the lake-side grasslands remains short much of the year due to constant grazing by plains game and livestock, possibly limiting its daytime utilization by elephants.

5. CONCLUSION AND IMPLICATIONS FOR CONSERVATION OF ELEPHANTS

Lack of elephant sightings in the community area suggests that elephants are increased becoming constricted to the protected areas and, are only erratically using areas outside protected areas. The presence of elephants in Manyara Ranch suggests that decisions by elephants on whether to occupy an area are largely determined by safety consideration. However, other factors such as water presence proximity and habitat quality are crucial.

While this study as well was a baseline survey, it enhances our understanding of the effect of human and ecological factors in elephant landscape use. These factors need to be put into consideration in planning for elephant

conservation in TME. Maintaining suitable habitats for elephants by maintaining areas with woody vegetation, and through improved surface water provision, particularly in the MR, and CA and are recommended. There is urgent need to secure critical elephant habitats, particularly those that provide connectivity across elephant core areas. These include areas used by elephants for movement between, MR and TNP, LMNP and MR, and MR and Esimingori hills (an area that has not been surveyed but is known to provide critical elephant habitat). Protecting these areas can help avert problems associated with high local elephant densities [33] and maintain ecological connectivity between core protected areas [13]. Efforts to conserve these areas require the goodwill of the local people who own the land. We recommend the establishment of Community Based Conservation Programs (CBCPs) such as Wildlife Managed Areas (WMAs) and village land management strategies to safeguard these areas from further degradation [34,35].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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