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Investigation of the effect of poaching on African elephant (*Loxodonta africana*) group size and composition in Ruaha National Park, Tanzania

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ABSTRACT

Monitoring the impacts of poaching on wildlife is crucial to the management of ecosystems and wildlife populations. Previous studies have shown that poaching can affect the demography, reproduction and behavior of wildlife. For African elephants (*Loxodonta africana*), poaching has been shown to affect population numbers, structure, breeding system, behavior and activity patterns. This study investigated whether there were significant differences in group size and composition of African elephants in Ruaha National Park, Tanzania between areas of high- and low poaching levels, based on the 2013 whole-ecosystem aerial census, which we used as a proxy for poaching pressure. Elephant group size and composition were recorded along 417.6 km of monthly transects from May to November 2016, and again from May to November 2017. Comparison of cow/calf group sizes revealed that the group sizes were larger in areas with low poaching pressure. The dependent-to-adult female ratio was higher in areas with low poaching pressure, while the proportion of adult females was higher in areas with high poaching pressure. The proportions of cow/calf and mixed group types were higher in areas with low poaching pressure. A higher proportion of bull groups were seen in areas with high poaching pressure, which could be evidence of a risk response strategy. Therefore, poaching has significantly shaped grouping patterns, composition and has caused reproductive suppression in Ruaha elephants. We recommend a genetic study of this elephant population to establish the degree of relatedness among families to understand the extent of social structure breakdown caused by social stress due to high poaching pressure in the past years.

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Introduction

Over the 2006–2015 period, Tanzania witnessed increased wildlife poaching in its protected areas. This crime has a detrimental effect on the structure and functioning of savannah ecosystems, national economy and security [16]. Wildlife poaching undermines tourism, one of Tanzania's foreign exchange earners (contributing 25% of total exports earnings and 17.5% of GDP), since charismatic species, including elephants, mainly stimulate the sector, which employs about 500,000 Tanzanians (BoT, 2017) [2]. However, on 16 June 2019 in Arusha, the then Minister for Natural Resources and Tourism stated that wildlife poaching in Tanzania has declined by 80%.

The African elephant (*Loxodonta africana)* is the largest extant terrestrial mammal in the world, found across 37 countries in Africa. Elephants are highly intelligent and social animals and play an important role as ecosystem engineers [12]. Elephants are also of conservation concern as their numbers are in decline. Between the last African Elephant Status Report in 2007 and the most recent in 2016, there has been a decline of approximately 104,000–114,000 elephants in Africa, predominantly due to poaching for the ivory trade [31]. The population of African savannah elephants are also threatened by human-elephant conflict and habitat loss [8,26,32]. Besides causing a decline in wildlife numbers, poaching affects social, demographic, and behavioral characteristics of wildlife populations [25]. For elephants, populations experiencing medium to high levels of poaching are characterised by fewer calf and old individuals, a biased adult sex ratio in favor of females, and a lower calf to adult female ratio within groups [15]. Poaching may also reduce group size by targeting old individuals and interfering with the breeding system and unit structure in elephant society [3,25]. However, in some cases, poaching has also resulted in large aggregations of elephants (e.g., Queen Elizabeth National Park), as a risk response strategy [25].

This study aimed at investigating the effect of poaching on elephant group size and composition in Ruaha National Park (RUNAPA), at the core of the Great Ruaha-Rungwa Ecosystem (GRRE), which is renowned for the largest elephant population in East Africa [31]. However, over the past years, heavy poaching pressure for the ivory trade has affected the long-term population demography, tusklessness and behavior of elephants in the ecosystem [15]. The study compared the elephant group size and composition between areas with high and low density of elephant carcasses as proxies of high- and low poaching pressure [6].

The Tanzania Wildlife Research Institute (TAWIRI) has been conducting a series of aerial counts in GRRE. Other studies include elephant distribution, feeding behavior and a possible over-population problem [4],[5], and impact of elephant browsing on vegetation [23]. More recent studies include the ongoing research project by the Southern Tanzania Elephant Programme (STEP) on elephant distribution, density, abundance, movement, home range and habitat use, activity patterns and evaluation of the effect of poaching on elephant demography, behavior and tusklessness [15]. Nevertheless, there is insufficient information about elephant group size and composition in RUNAPA. Hence, this study evaluates the effect of poaching on elephant group size and composition in RUNAPA to help the Park management develop better protection strategies to supplement the ongoing population census in this important ecosystem.

Systematic data collection in areas with different levels of poaching pressure in RUNAPA was conducted in 2016 and 2017. The carcass density distribution map reported by TAWIRI through aerial counts in 2013 in GRRE was used to define areas with high and low poaching pressure [28]. In areas of high-poaching pressure, it was expected to see small group sizes, and reduced number of adult females with lower dependent- to- adult female ratio [13,15].

Material and methods

Study site

The Ruaha National Park, situated in south-central Tanzania, is the country's second largest National Park (20,226 km^2) and is part of GRRE (43,000 km^2), which holds not only the largest elephant population in Tanzania, but also one of the most important populations in East Africa (TAWIRI, 2013, [19]). However, the elephant population in GRRE decreased by 50% from 31,625 in 2009 to 15,836 in 2015 [29]. High carcass rates indicated that the elephant population in GRRE was experiencing substantial unnatural mortality during this period. Again, elephant density in GRRE showed a marked decline between 2006 and 2015, which was concurrent with an increase in the index proportion of illegally killed elephants (PIKE) reported by CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) between 2009 and 2015 [15].

In RUNAPA, the dry season spans May to November, and the wet season is in December to April, with an average rainfall of 650 mm [7]. The Park is bounded by two major rivers, which are important sources of water for wildlife: the Mzombe River in the north and the Great Ruaha River in the south. Several habitats can be found in GRRE including savannah woodlands, swamps and riverine areas, which have resulted in occurrence of diverse fauna and flora assemblage [4,5,30].

Poaching pressure

We used the distribution of elephant carcasses from TAWIRI aerial surveys in 2013 to define areas with high and low elephant carcass densities as proxies of high- and low poaching pressure [6]. The 2013 elephant carcass map was chosen because in this year, the census report showed a drastic decline in elephant population by 37% in four years (2009–2013).

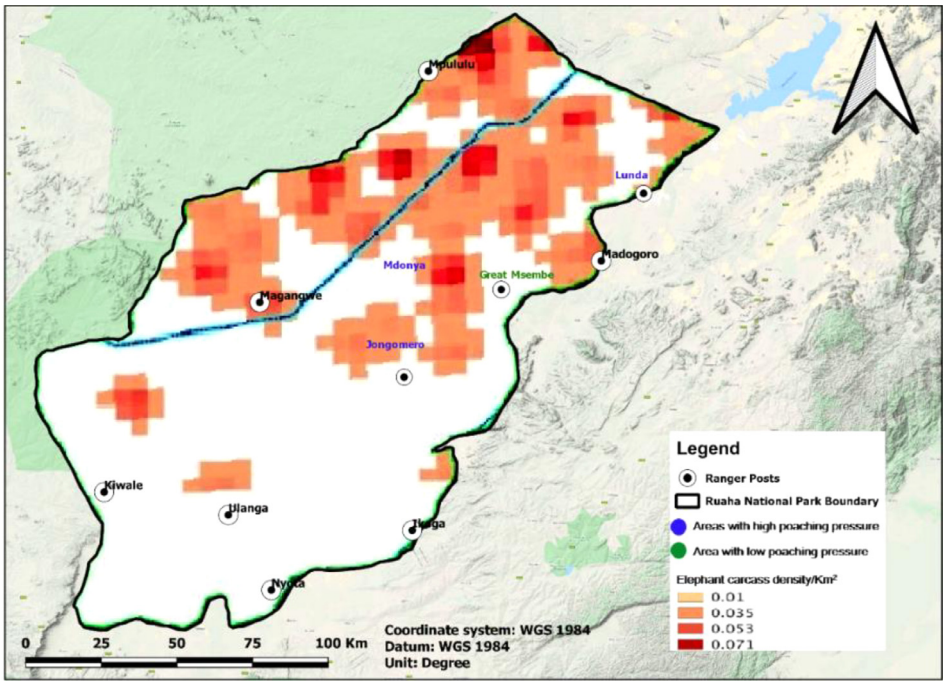

Fig. 1. Distribution of elephant carcasses in RUNAPA. (Base map source: TAWIRI dry season aerial census report, 2013).

The elephant carcass density per km^2 between 0.035 and 0.071 was used to define high carcass density while that between 0 and 0.01 was used to define low carcass density (Fig. 1). Since Lunda, Jongomero and Mdonya had higher elephant carcass densities, they were categorised as high-poaching pressure areas, while the Greater Msembe areas (Msembe, River drive, Kimilamatonge, Mwagusi and Mbagi) had lower elephant carcass densities, and thus were categorised as low-poaching pressure areas. Therefore, in this study, the Msembe areas as park headquarters and being associated with fewer elephant carcasses in their immediate vicinity also has most tourism activity compared to other areas of the park, this also provide additional protection as discussed by [6] and Schlossberg et al., [26]. Additionally, Msembe as a low poaching pressure area is dominated by suitable habitats and other resources such as better forage quality for elephants and bound to important dry season water sources, the Mdonya, Mwagusi and Great Ruaha rivers ([27], pers. Comm.).

Data collection

Elephant sightings were collected using four monthly vehicle-based transects following the park's road infrastructure as per the method initiated by STEP for its ongoing elephant monitoring project in RUNAPA. Along transects, the method involved driving a vehicle at a constant speed of less or equal to 30 km/h while recording all live elephant sightings. These transects passed through the areas with high and low carcass distribution reported by TAWIRI. These transects include: Jongomero-Msembe (MT1), Msembe-Lunda (MT2), Serengeti Ndogo-Mwagusi (MW) and Mdonya-Msembe (MD), (Fig. 2). In addition, these transects followed rivers (Great Ruaha, Mdonya, and Mwagusi) which are the main source of water during dry season. The transects that passed in areas with high poaching pressure were combined as one sample, while those passed through areas with low poaching pressure were combined to form the second sample. The selected transects also passed in areas of the park with lower altitudes, more suitable habitats, and more road network, where elephants are less shy, less elusive, and more calm to allow for demographic assessment. The other areas of the park such as Magangwe, Mpululu, Ulanga and Mzombe are higher altitudes dominated with nutrient-poor Brachystegia woodlands (Miombo), and less road infrastructure, in which elephants move constantly during the night, are shyer and more elusive to allow for demographic assessment.

The ground data collection for this study was conducted in dry seasons between 2016 and 2017 (Table 1). This is because in the wet season, rains influence the elephant dispersal as food and water resources become more available across the park [17]. Moreover, in the wet season, dense vegetation reduces elephant detectability and restricts surveys to small areas with stable road network. For each elephant sighting, group size, group type, sex and age structures were recorded.

Elephant age class assignment was based on shoulder height, body and head shape, back length and size of the tusks [21,25] and was placed into one of the following age classes; 0–4, 5–9, 10–14, 15–19, 20–24, 25–39 and 40+.The GPS coordinates for all sightings were taken. In order to avoid double counting of individuals, photos were also taken [15].

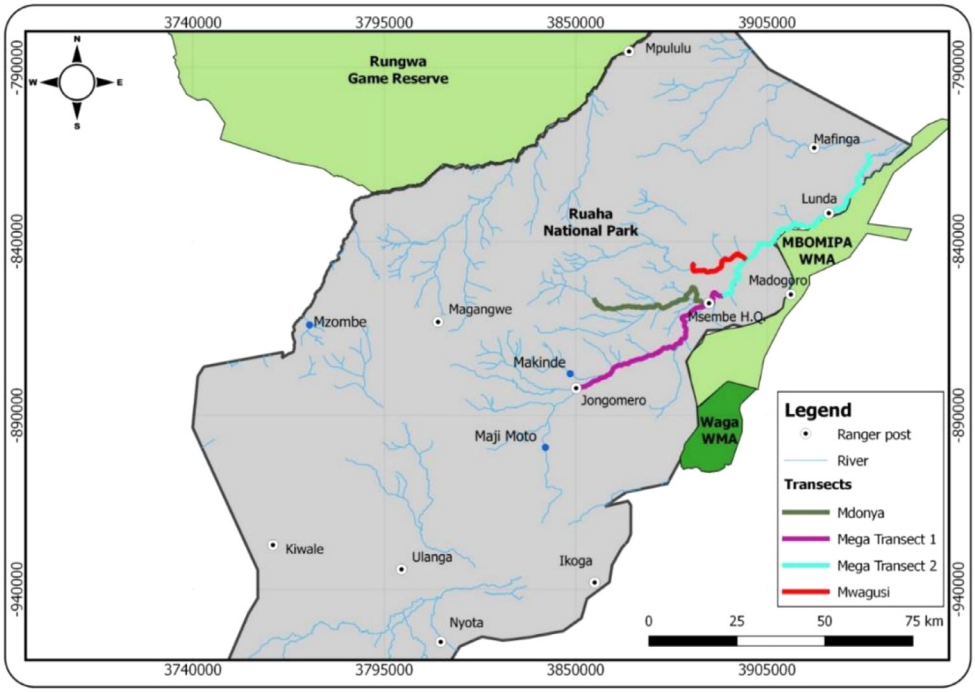

Fig. 2. Map of RUNAPA showing survey study road transects.

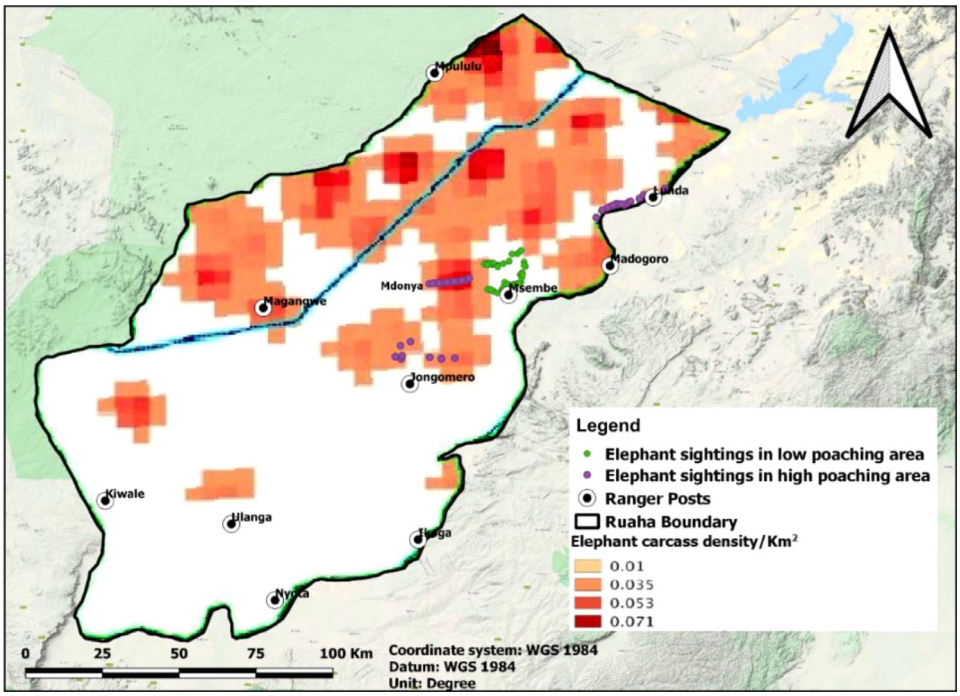

Fig. 3. Elephant sightings between areas with low and high poaching pressure in RUNAPA. (Source: Base map, TAWIRI dry season census report, 2013).

Table 1
Data collection effort.

Transect name	Distance (km)	Repeats (2016)	Elephant sightings (n)	Average encounter rate (n/km)	Repeats (2017)	Elephant sightings (n)	Average encounter rate (n/km)
MT 1	65.7	7	85	0.184	7	72	0.156
MT 2	76	7	66	0.123	7	87	0.163
MW	21.8	7	50	0.327	7	51	0.333
MD	45.4	7	48	0.138	7	26	0.101

In elephant society, cow/calf groups are considered to be the most cohesive social unit and determine the sustainability of elephant populations [19,21]. For this reason, this study considered only cow/calf groups in our assessment of group size, the ratio of dependents to adult females at the group level and the proportion of adult females present in the herd. Also, according to Poole [25], female elephants typically begin reproduction between the age of 10 and 15 years based on breast index. We used a similar metric to categorize adult females and we also classified them as young adult 10–19.9 years; 20–24.9 middle adult; and old adult 25–40+ years [13].

All individuals < 10 years old were considered as dependents. All cow/calf groups seen together with bulls were defined as mixed groups. A bull group consisted only of males, while an aggregation in this regard was all groups of elephants with more than fifteen individuals and with more than one family unit with or without adult males, and the single adult males were considered as lone bulls [25].

Data analysis

Relationship between elephant carcass densities and elephant sightings data

The elephant carcasses distribution base map and our elephant sightings location data were processed into the same Coordinate Reference System [33] through geo-referencing and projection processes. Then, the field elephant sightings data were overlaid on the geo-referenced elephant carcass distribution base map to see where the observations fell into the elephant carcass density features on the base map. The visual interpretation was used to describe elephant sightings data that fell into the areas with low and high carcass densities as proxies of low and high poaching pressure respectively (Fig. 1).

Group size

We used 92 cow/calf group observations from areas with low poaching pressure and 48 cow-calf group observations from high poaching pressure areas for comparing group sizes. R software version 3.6.1 equipped with R Studio version 1.2.1335 was used for data analysis. We used poaching pressure categorized as high and low as predictors and elephant group size was treated as response variable in Generalized Linear Mixed Models with Poisson regression. To avoid auto-replication, we used “transect ID” as random factor to increase independence of elephant group size. Due to presence of statistical significance difference in prior contrast model, we utilized “tukey test” with multicom () package to determine the differences existed among the poaching pressure categories.

Group composition

We used 47 cow/calf group observations from areas with low poaching pressure and 30 cow/calf group observations from areas with high poaching pressure for comparing the dependent-to-adult female ratio at the group level and the proportion of adult females. We used poaching pressure categorized as high and low pressure as predictors and dependent-to-adult female ratio (< 10 years old individuals divided by the number of adult females at group levels) as response variable in Generalized Linear Mixed Models with Gaussian distributions. To avoid auto-replication, we used “transect ID” as random factor to increase independence of dependent-to-adult female ratio. We also used poaching pressure categorized as high and low pressure as predictors and proportional adult females as response variable in Generalized Linear Mixed Models with weighted binomial regression. To avoid auto-replication, we used “transect ID” as random factor to increase independence of the proportion of adult females.

We used 147 elephant observations from high poaching pressure areas and 244 elephant observations from low poaching pressure areas to compare composition of group types. We used Pearsons’ Chi-square test through utilization of Chisq.test () function in R. Due to presence of statistical significance difference in prior contrast results, we utilized “chisq.posthoc.test” from chisq.posthoc.test () package in R to determine the differences existed in each group types with poaching pressure categories.

Results

Group size

The cow/calf group sizes between areas with high poaching pressure differed from those with low poaching pressure in the park. The group size in areas with low poaching pressure ranged from 3 to 15 individuals, while cow/calf group

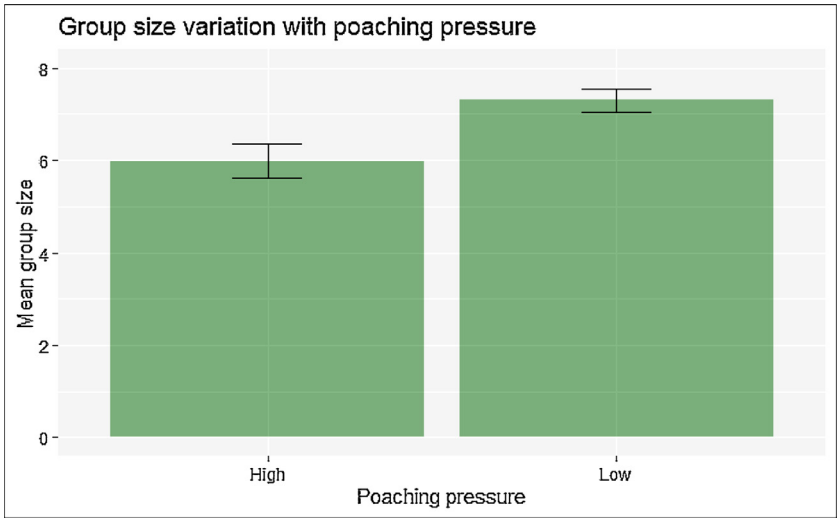

Fig. 4. Mean cow/calf group sizes between areas with high vs low poaching pressure in RUNAPA.

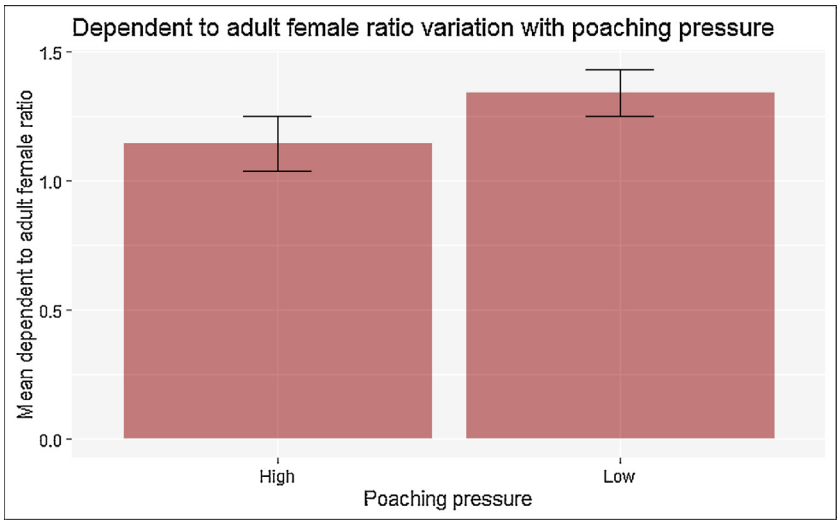

Fig. 5. Mean dependent-to-adult female ratio at group level between areas with high vs low poaching pressure in RUNAPA.

sizes in areas with high poaching pressure ranged from 2 to 13 individuals. The mean cow/calf group size in areas with low poaching pressure was 7.29, while in areas with high poaching pressure was 5.97 (Fig. 4). The median cow/calf group size as a measure of cohesive social unit in elephant society was 7 and 5 in areas with low and high poaching pressure respectively. We found that poaching pressure has a significant impact on cow-calf group size ($F = 7.937$, DF=1, $P = 0.01$), (Fig. 4). Furthermore, we found that all two categories of poaching pressure (high and low pressure) were significantly different (Tukey test, $p = 0.01$). There was significant increase in mean cow-calf group size in area with low poaching pressure (Estimate $= 0.19 \pm 0.07$ SE, $Z = 2.82$, $P = 0.01$).

Group composition

Mean dependent –to- adult female ratio at the group level. A total of 132 dependents and 144 adult females from 47 cow/calf groups were observed with complete demography (groups with all of its individuals being aged and sexed) from areas with low poaching pressure, while 87 dependents and 79 adult females from 30 cow/calf groups were observed with complete demography from areas with high poaching pressure. We found that poaching pressure has significant impact on the dependent-to-adult female ratio, ($F = 1.85$, DF=1, Confidence Interval (-0.08 – 0.48). However, the dependent-to-adult female ratio increased in areas with low poaching pressure (Estimate $= 0.29 \pm 0.22$ SE, $t = 1.36$), (Fig. 5).

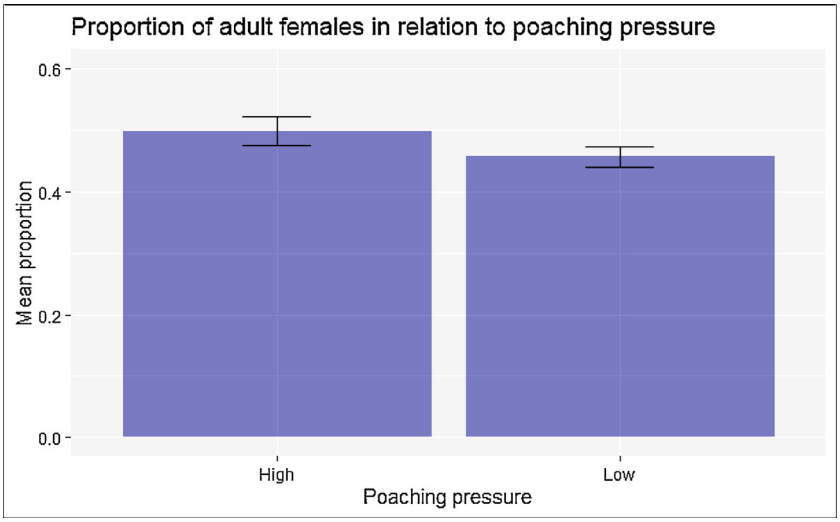

Fig. 6. Mean proportion of adult females > 10 years old between areas with high vs low poaching pressure in RUNAPA.

Table 2
Chi square post hoc test results for group types with p -values in high and low poaching pressure areas.

Group type (s)	p -value
Bull group (BG)	<0.01
Cow/calf (CC)	>0.05
Lone bull (LB)	>0.05
Mixed group (M)	<0.01

Proportion of adult females. The mean proportion of adult females (>10 years) was higher in areas with high than low poaching pressure though showed no differences ($F = 0.32$, DF=1, $P > 0.05$). The proportions of Ruaha female elephants above 10 years old in areas with low poaching pressure consisted of 34.0% young adults, 26.0% middle adults and 41.0% old adults ($n = 144$), while in areas with high poaching pressure the proportions consisted of 35.0% young adults, 22.0% middle-aged adults and 44.0% old adults ($n = 79$). Proportion of adult females was not statistically significant in areas with high and low pressure (Estimate $= -0.32 \pm 0.57$ SE, $Z = -0.56$, $P = 0.57$), (Fig. 6), but the females in areas with low poaching pressure were seen to have better calf recruitment due to higher dependent-to-adult female ratio and reduced stress.

Composition of group types. At least 244 elephant groups were observed from areas of the park with low poaching pressure, while 147 elephant groups were observed from high poaching pressure areas. We found that group types are not uniformly distributed in the areas ($X^2 = 25.09$, df $= 3$, $p < 0.01$), in which all group types were more predominant in areas with low poaching pressure except bull groups (Fig. 7). Furthermore, through utilization of χ^2 post.hoc.test, we found Bull Group (BG) and Mixed Group (M) were significantly different between high and low poaching pressure ($p<0.01$), while other group type categories were not statistically significant ($p>0.05$), (Table 2).

Discussion

The study found that areas with high poaching pressure had cow/calf groups with fewer individuals while the largest cow/calf groups were found in areas of the park with low poaching pressure. This is because the areas of the park with high poaching pressure experienced a high disturbance with minimum security and low tourism activity, with increased risks for breeding and decreased calf survival. Elephants are known to have enhanced ability to remember past experiences, enabling them to avoid areas in which they have experienced danger or social stress. On the other hand, areas of the park with low poaching pressure experienced more security, increased tourism activity, reduced risks for breeding and increased calf survival. This interpretation is supported by the finding that the dependent-to-adult female ratio was higher in the low elephant carcass density areas of the park, suggesting that areas with low poaching pressure had better recruitment than those areas of the park with high poaching pressure, which had fewer individuals younger than ten years old. The study conducted in Queen Elizabeth National Park in Uganda, showed that the largest family group sizes of elephants were found in areas with high poaching pressure, while the smallest family group sizes were found in areas of the park with low poaching pressure with high protection [24], which is contrary to our findings. The social and ecological stress caused by

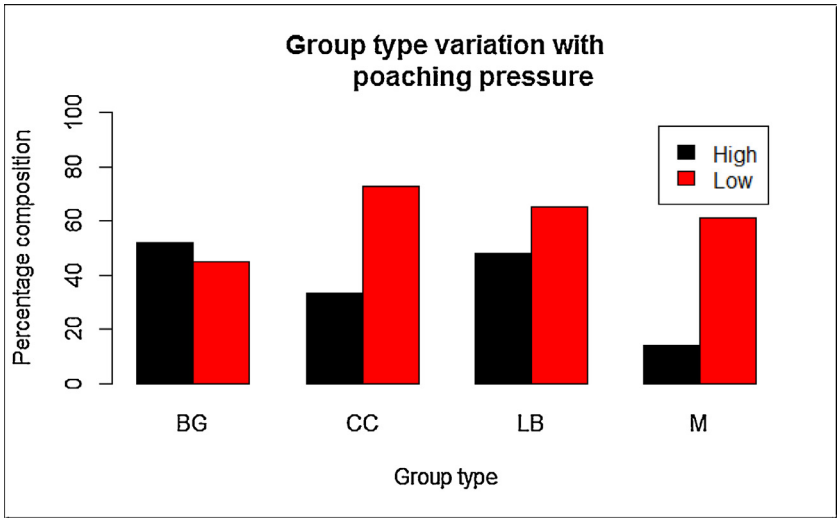

Fig. 7. Percentage composition of elephant group types in areas with high and low poaching pressure in RUNAPA. Letters, BG = Bull groups, CC = Cow/calf, LB = Lone bull, and *M* = Mixed group. .

poaching pressure in elephant society can lead into the breakdown of family groups as a result of forming up large groups as a risk response strategy. The family group sizes in unpoached populations such as the Amboseli population contain an average of about 9.4 individuals with a range of 2 to 29 [1,22]. This is larger than that we found in RUNAPA, of 7.29 in areas of the park with low poaching pressure and 5.97 in areas of the park with high poaching pressure, but higher than that in Mikumi National Park, which is 2.2 [14].

The mean dependent-to-adult female ratio, which is the ratio of calf under the age of 10 to the number of breeding females above 10 years at group level, acts as a breeding indicator. A higher ratio indicates better calf recruitment and faster population growth, and vice versa [19]. This indicator declined between 2009 and 2015 [15] but increased between 2016 and 2017 of this study. The dependent-to-adult female ratio in areas with high poaching pressure was lower (one to 1.17 in favor of dependents) than in areas with low poaching pressure (one to 1.33 in favor of dependents), (Fig. 3). This is because of the poaching pressure imposed between 2010 and 2015, which interfered with the breeding system (low recruitment, high calf mortality, few oestrus females and few musth bulls due to high reproductive stress). The increase in mean dependent-to-adult female ratio between 2016 and 2017 is due to increase in recruitment and survivorship (allomothering) of calf under the age of 10 years. Calf between the ages of 0–5 years old have the 30.0% chance of survival in the two years following their mother's death, while juveniles between the age of 5–10 years old have a 48.0% chance of survival [25]. But these ratios in areas with low and high poaching pressure in Ruaha were all lower than the ratios from well-protected populations of Tarangire (1.92) and Serengeti (1.98) but higher than the heavily poached populations of Ugalla (0.67) and Selous (1.05) as assessed in 2009 [15].

The mean proportion of Ruaha female elephants above 10 years old was slightly higher in areas with high poaching pressure. This may be due to the fact that during this study, we observed a majority of adult females in areas with high poaching pressure being tuskless and therefore less targeted by poachers, and this is also supported by [15]. However, the females in areas with low poaching pressure are seen to have better calf recruitment due to higher dependent- to- adult female ratio and reduced stress of poaching pressure. In comparison with the Mikumi elephant populations, which are regarded to have been subjected to high poaching pressure, the proportions looks varying, where by the Mikumi elephant populations consisted of 28.0% young adults, 44.2% middle-aged adults and 27.4% old adult females (n = 218), [14]. The variation in proportions between Mikumi (high poaching pressure area) and Ruaha for the areas with high poaching pressure may be due to differences in sample sizes and assessment methods used.

The lower percentage of the mixed groups in high poaching pressure areas of the park from this study possibly influenced recruitment suppression as shown by the lower ratio of dependent-to-adult female at the group level as also discussed by [11] and Mondol et al., [20].

The high percentage of bull groups within areas with high poaching pressure may be caused by behavioral risk response whereby adult male elephants form semi-permanent groups to increase vigilance as solitary single adult males are more vulnerable to poachers.

However, elephants are a species with large range requirements and migratory behavior [9,10,26] whereby in many populations, annual movements is a common phenomenon [18]. Due to the fact that our study areas (high and low) poaching pressure seem to be in close proximity, hence, during this study elephants might also have been moving between the two areas. Therefore, in order to minimize the impact of close proximity among the high and low poaching areas and to avoid double counting, individual photos were taken and individual elephants were given an ID code and identified by features

of their ears and tusks and an elephant ID database between the two areas was developed. The individual ID's were also helping us get to know families and their home ranges.

Conclusion

Poaching has shaped the grouping patterns of RUNAPA elephant populations. Areas of the park with low poaching levels have the largest cow/calf group sizes, while areas of the park with high poaching levels have the smallest cow/calf group sizes.

It is also clear that poaching has significantly caused reproductive suppression in RUNAPA, as indicated by the presence of lower dependents to adult female ratio in areas of the park with high poaching pressure and poor security. Poaching has also shaped the grouping patterns of female elephants in RUNAPA in areas with high poaching pressure by having smaller group sizes due to the killing of other members and lack of allomothering (in which group members work together in protecting calf and providing experiences towards danger). There is no significant difference in the age of adult females between the areas with high poaching pressure and areas with low poaching pressure. Based on the role of matriarchs in elephant herds, more research is required to study matriarch ages among families to understand the sustainability of this elephant population. This is because during this study we observed few old matriarchs above the age of 40 years old. However, a longer period of time is required to observe a change as a result of reduced poaching pressure.

The proportions of cow/calf and mixed groups were higher in the areas of the park with low poaching levels. On the other hand, a higher proportion of bull groups were seen in areas of the park with high poaching levels, which could be evidence of a risk response strategy as lone bulls are more vulnerable to poachers.

We recommend a genetic study of this elephant population to establish the degree of relatedness among families. This will help us to understand the social structure breakdown caused by social stress due to high poaching pressure over the last fifteen years. This is because during data collection for this study, we observed a number of dependents (individuals below 10 years) in cow/calf groups which were more or less of similar age. This may be an indicator of surviving orphan calf that have joined other families as a result of lost mothers and other family members.

Declaration of Competing Interest

None.

Acknowledgment

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