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Analysis of demographics, male and female social groups, and movements of the *Loxodonta africana* using camera traps in the Makgadikgadi Pans National Park, Botswana

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Abstract

African savannah elephants face threats from ivory poaching, competition for resources with humans, habitat loss and land degradation. Extensive surveys have estimated a wild elephant population of approximately 350,000 individuals (30% drop in less than a decade).

This study contributes to the ongoing projects in Botswana's Makgadikgadi Pans National Park (MPNP), that Elephants for Africa (EfA) have been implementing since 2012. Elephants from different areas will not behave and/or interact between groups the same way, plus the high male elephant density at the MPNP can give us insights on the less studied male society. Also, trophy hunting and the illegal trade usually target old male individuals, but it has been determined that they transmit intergenerational knowledge to younger individuals, making them key individuals within the male society.

This 3-year study span (June 2014-April 2017) used data collected from eight camera traps alongside "elephant highways" to determine elephant activity changes, elephant presence growth, group composition and size. The area can suffer significant changes of water, food and opportunities between dry and wet season, making seasonality an important variable to consider. The project revealed that elephant activity had grown overtime in the MPNP. Seasonality influenced male sightings, and a negative correlation between rainfall-elephant sightings was found. Also, adult males were more prone to form groups when travelling, and the number of groups was higher during the dry season. Ultimately, more elephant night-time activity was captured during the crop season, so, further mitigation research to the current human-elephant conflict in the area is recommended.

Keywords: African savannah elephant, "elephant highways", human-elephant conflict, seasonality, male elephant groups.

Introduction

The 60% drop of the African savannah elephant (Loxodonta africana) population since 1970, is attributed to habitat loss, land degradation, poaching and human-elephant conflicts. Steps to protect the species have been taken: the IUCN Red List re-classification from Vulnerable to Endangered (Gobush, K.S. and others, 2021), improvement of anti-poaching measures, protection of their habitats, human-elephant coexistence, and research on their migrations and behavioural patterns.

The study area is the western boundary of the Makgadikgadi Pans National Park (MPNP), which lies on the south-west of the Okavango Delta in Botswana. Over the 3900km2 range of the MPNP, diverse landscapes can be found, including a series of arid salt pans, water reaching in via the Boteti River (study location; Fig 1) and the Ntetwe Pan, summer savannah grassland, wooded areas, etc (Ecosystem for Africa, 2016). The MPNP can suffer serious droughts that can cause wildlife fatalities.

In Botswana, research is being carried out by many organizations to improve the understanding of the 130,000 elephants that spend time in the country and preserve one of the species' remaining strongholds (Adams and others 2017). One of these organizations is Elephants for Africa (EfA), which thanks to the collaboration with the University of Bristol, provided the datasets that form this thesis.

Elephants are ecosystem shapers. They are considered grazers and browsers, and their feeding has positive effects in the ecosystem, especially to herbivores, because elephants are seed dispersers, create gaps in the vegetation allowing new plants to grow, and create pathways during the process, which other animals can use (Coverdale and others 2016). “Elephant highways” help foraging strategies by connecting commonly used resources and landscape features (drinking and feeding points, avoid dangerous areas, resting places…).

They form separated social groups on the basis of sex, with females and their young establishing lifelong bond-groups; and with adolescent (10-20 years), subadult (21-26 years) and adult males (>26 years) living independently or forming temporary associated groups (Shannon and others 2008). Segregation effects can be observed when elephants select their home areas, with independent males choosing habitats on the basis of forage availability, maximizing their fitness and body size (Corti and others 2002). Females on the other hand, primarily selecting habitats that provide protection and safety from predators, even if this requires a trade-off in nutritional return (Conradt 2005; Main and others 1996). This could not be clearer, than in MPNP, where the population is mainly composed of males (Evans 2019), so the dynamics and interactions will differ compared to other more mixed populations. Most research has focused on females, and the few recent male elephant related studies are showing how important male society is to conservation (Burke and others 2018; Evans 2019).

Due to human activity increases and the requirement for large areas to exploit for agriculture/infrastructure, the competition and conflict between elephants and humans has intensified (Trade 2019). Also, cultural knowledge on how to act in the presence of, and live with elephants, is insufficient due to the lack of recent exposure in the region, since prior to 2009, the Boteti River had been dry for 18 years, and elephant numbers were low. Since then, a high number of species have been attracted to the area, and there's been increases in the number of human-elephant incidents (Mayberry and others 2017). Rural communities are being affected by elephant crop raiding with great economic losses (Chamberlain 2018). Understanding the crop raiding dynamics around the MPNP boundaries, can help communities to coexist with wildlife, and minimize negative impacts.

Allen and others (2020) have shown that older and experienced elephant males have a key role to play in younger males' survival, by passing on skills, knowledge and leading younger males. Research suggests that older males hold a similar position in male society as matriarchs in female herds, but with transitory groups and more passive leadership (Allen and others 2020; K. Evans and Harris 2008). These findings challenge the belief that selective removal of old males by trophy hunting and poaching does not have a harmful effect on elephant populations, and due to the importance of their role, protecting these pivotal specimens is needed (Burke and others 2018).

Seasonality can be a strong factor in savannah environments, during the dry season (monthly rainfall < 10mm, usually April-October) resources are harder to find and more limited, or during the wet season (monthly rainfall >10mm, usually November-March) when hard to predict sprouting of vegetation and resources start appearing (may require experienced knowledge to locate). Consequently, it is important to differentiate these two periods to get conclusive and significant results.

The data obtained and all these factors and facts, aimed the research towards the following hypothesis:

- **H1**: Female and male demographics of elephants utilising the “elephant highways” have changed over time.
- **H2**: Adult males (>26+years) are more often found in groups.
- **H3**: Male elephant groups are predominantly made up of adult males.
- **H4**: More male groups are found utilising the elephant highways in the wet season.
- **H5**: Elephants utilising the “elephant highways” close to crop fields and human settlement areas more during the cropping season.

Methodology

The project used data obtained by Elephants for Africa (EfA) using camera traps. The EfA camera traps (Reconyx HC600 Hyperfire) were set up beside 8 “elephant highways” (Fig. 2). The project dataset is between June 2014 till April 2017, and collected a large volume of images (№ = 17729).

The camera trap image extraction was done through the citizen science platform Zooniverse (https://www.zooniverse.org/) by SnapShotSafari. Users went through the images and were given distinguishing features to identify the species captured (Simpson and others 2014). If the statistical significance specified in each of the questions was meet by the users answers, the software classified the images accordingly. Human observers received online training through detailed instructions and workflows to identify the species captured, determine if they were using the “elephant highways”, and if elephants were identified, sex and age was also determined (Subadult <26 years or Adult >26 years). Raw initial data obtained at SnapShotSafari was converted through various software (Panoptes, Anaconda and Kinesis) to extract readable CVS file data.

When mentioning elephant herd or group, we are referring to the sequence from the first elephant triggering the camera to the rearmost individual captured leaving the location. The camera trap view range is approximately 50 meters, but female elephant aggregations are usually within 50-100 meters (Nandini and others 2018). The majority of sequences captures occur within 1-8 minutes (Dai and others 2007). Checking the EfA dataset images specifically made us set a 5-minute cut-off to indicate the next passing herd. This cut-off inferring was applied to the full dataset using Phyton. Since the elephant population of the MPNP is mainly transient (Pitfield 2017), most of the sightings aren’t repeated, so we rather used a large dataset for measuring elephant activity, than individual identification and a small dataset.

EfA maintained an ongoing daily data recollection for 3 years, unfortunately, in 2016 the camera traps went off for 3 months (April, May and June) and were redeployed afterwards, in the same positions and direction, as when they were first deployed. The missing data were imputed using the Multiple Imputation method (SPSS). It helped answering the first hypothesis which required a completed, seasonal and homogenic time series.

When separating by seasonality, the wet season considers those months presenting rainfall records >10 mm. and the dry season are those with <10 mm. of rainfall. Also, the MPNP suffered severe drought conditions during 2015, altering the usual wet season period.

For our first hypothesis (H1), if female and male demographics had changed over time, daily sighting were calculated by extracting all female herds and male sightings. By considering breeding herds instead of female individuals, potential errors on the count of specimens captured can be avoided. Female herds are very stable, so studying them as a unit is reasonable.

Some extra information that was thought of being useful was also gathered. Statistical tests were conducted (SPSS): one-way ANOVA between the 3 years span to detect annual changes, median comparison test between seasons to determine differences due to seasonality, regression analyses linking rainfall to elephant activity, and we also obtained the growth of the elephant activity overtime; to check the growth of the elephant activity in the area, we used the moving average method to prepare our dataset (subsets of the full data set adapted every 3 days); the Exponential Growth and Poisson regressions determined the growth without having to extract seasonality.

For our second hypothesis (H2), we filtered the data, to get only sightings of 1 or more adult males (>26 years) and then compared the adult males travelling in groups versus the adult males found alone. Favourable cases were those where the number of male individuals that constituted the groups were 2 or over. Note that if a group contained X adult males, we considered X as nº of favourable cases. The Binominal test checked if the proportion of adult males (>26) forming groups compared to those lone adult males (>26) was >0.5.

The third hypothesis (H3) consisted of checking if male groups are predominantly made up of adult males. We obtained all the groups (N≥ 2 individuals) and considered as favourable cases those groups where L [(nº adult males in the group)/N (group size)]>0.5 accounting this binary data result as 1. After the assignation of binary characters, a Chi Square test was performed to the outcome dataset.

To determine if more male coalitions are found in the wet season (H4), all groups formed during the wet and the dry season were accounted. A comparison was made using the Chi-square test, to check for significant differences in the number of male groups due to seasonality. Proportional and comparable values were calculated by giving the percentage of specimens conforming the groups out of the total of individuals sighted per season. A classificatory system to represent grouping traits (age and size) of the most frequent male groups composition in the area was assessed.

For our last hypothesis (H5), related to human-elephant conflicts, the cameras were placed facing the "elephant highways", so we were only able to assess if there was more or less elephant activity at MPNP areas close to Khumaga and fields during the cropping season (March, April, and mid-May), not if there was actual crop raiding happening. A Median test compared the daily elephant activity during the cropping season, versus the levels found during the non-cropping period. A median comparison of the year 2015 night-time elephant activity between cropping and non-cropping season datasets was also made.

Results

- ***Elephant demographics of male and females utilising the "elephant highways" (H1).***
  - *Elephants daily sightings by CT overtime.*

Fig. 3A, shows a temporal series representing the male elephant daily captures. From Jun-14 to Apr-17 we have an overall mean of 21.01 daily sightings. 2015 (drought year) has the highest daily sighting mean values. Even though some daily sightings might be higher during November and December (>60), the overall monthly sightings had recorded the highest values at the end of the wet season and beginning of the dry season months. June and July, the coldest months in Botswana, registered a decrease of male sightings in every studied year, since lower temperatures may reduce the river usage. The temporal series seem to show some periodicity. The high variability of the dataset (variance of 122.05 and a standard deviation of 11.05) can be explained by the seasonality factor (at section *Dry and Wet season Box-plot and median non-parametric test analyses*).

Fig. 3B, shows a temporal series of the female elephant herds daily captures. From Jun-14 to Apr-17 we have an overall mean of 3.17 daily female herds sightings by CT. 2015 (drought year) daily female herds sightings mean wasn't the highest recorded. Months with outstanding peaks of the dataset can be found (>7.5) but seasonality does not seem to drive the female herds presence. Although some of the highest values are around and/or during the wet season, other months registered similar captures, making it difficult to identify any kind of periodicity on their movement behaviour. The dataset of female herds daily captures has a variance of 4.34 and a standard deviation of 2.08.

- *Over time elephant activity growth.*

A Poisson Regression analysis on the male activity dataset ($Y= e((6,99E-5*X) + 3,007)$), determined an increase of 7.17±2.80% over the 1062 days. For the growth regression model $Y= \exp(2.82310 + 0.00013 * X)$ a 12.79±4.33% increase overtime (4.26% annual increase).

An increase of 7.16±2.54% over the 1062 days of the project span, using the linear regression model ($Y=0.00147*X + 20.21429$). The R associated to the model is very low ($R=0.067$; $F= 4.8$; p-value= 0.029; Fig. 4A) but this was expected since we just wanted to determine the model growth.

For female herds, the Exponential Growth function $Y= \exp(B0 + (B1* X))$ could not be used since the dataset had 0 daily sightings ($Y=0$) in many data points. Instead, the Poisson Regression model instead of using the 0 daily sightings datapoints which wouldn't be able to be predicted by the equation, it transforms them into Ln (0.5) and adjusts the results.

For the growth of the female herds activity, we used a Poisson regression analysis, which found significant growth ($X2=8.56$; $df=1$; p-value= 0.003; Fig. 4B). The Poisson Regression model ($Y= \exp((0.000206*X) + 0.603)$) obtained an increase of 19.19±7.86% (6.39% average annual increase).

- *Dry and Wet season Box-plot and median non-parametric test analyses.*

The high variance that the daily sightings presented, made us think that the seasonality factor could have had some effect and aggravated the differences between seasonal datasets. Normality distribution rejected (Male p-value< 0.001; Female p-value< 0.001).

Males: Fig. 5A, show how the overall dry season median is 21 and the wet season is 17 males daily sighted, but the 85th percentile had larger daily captures during the wet season giving a more right-skewed distribution. The differences between the seasons medians are significant (Median Test p-value< 0.001), therefore, the null hypothesis is rejected.

To check the differences of the cumulative distributions of the dry season and the wet season months datasets, we conducted a Kolmogorov-Smirnov Test (Fig. 5B). Significant differences were found between the datasets seasonal distributions (Z= 3.052; p-value< 0.001) and the central tendency parameter. Also, the wet season data have higher variance (Variance= 161.082; Std. Deviation= 12.692) compared to the dry season (Variance= 85.392; Std. Deviation= 9.241).

Box-plot analyses have also been assessed to study the seasonality within each studied years: 2014, 2015, 2016 and 2017. Yearly analyses determined that the dry season has significantly higher medians for the male data, therefore, each year's dataset follows the overall tendency.

Female herds: *Fig. 6A*, show how the overall dry season months have a daily median of 2 sightings, the same as the wet season. The 3rd quartile values have larger daily captures during the wet season months giving a more right-skewed distribution. Almost not significant differences between the dry season and wet season were observed (Median Test p-value: 0.049), so in this case, yearly analyses are important to determine the importance of the seasonality factor in female herds activity.

The K-S Test (Fig. 6B) indicated non-significant differences between the distributions of each dataset (Z= 1.345; p-value= 0.054). Due to the Median Test being almost not significant and with non-significant distribution differences, it can be stated that, there is no evidence that there is a seasonality factor affecting female herds movements to the area. Higher variance found when analysing the wet season data (Variance= 6.181; Std. Deviation= 2.486) compared to the dry season (Variance= 3.727; Std. Deviation= 1.930).

As with males, female yearly Box-Plot analyses and Median tests were conducted. These comparisons showed that except the Jun-14 to Apr-15 period, which obtained significant differences, the rest show strong non-significant results, which indicates that no evidence was found on female herds overall tendency following a seasonal pattern.

- *Rainfall – elephant activity regression analyses*

These regression analyses can help to determine the elephant movement behaviour, to and from the river, when there is rain. In the case of males, significant changes in terms of their activity during the wet (Rainfall > 10mm) and dry seasons (Rainfall < 10mm) were found.

Fig. 7A, shows that with low rainfall (<10mm.) the datapoints obtained have high variance, since there is probably not enough rainfall to influence their behaviour, and the river still is the most important water body. Subsequently, when analysing datapoints from 10mm. to 45 mm. a decrease on the elephant male activity is observed, and the datapoints variance reduces. All three regression models were evaluated (without outliers) and significantly supported that with higher values of rainfall, sightings of males were lower: the Linear Regression model (R= 0.617; R2= 0.380; F= 30.693; p-value< 0.001) represented by the equation model [Y= -0.134*X + 16.826], the Exponential Growth model (R= 0.665; R2= 0.442 F= 39.613; p-value< 0.001) defined by [Y= exp(2.8091 + -0.0103*X)], and the Poisson Regression (X2=21.636; B= -0.011; df=1; p-value< 0.001).

Several biotic and abiotic factors can have an influence when modelling wildlife data, but regarding rainfall, our Linear model explains up to a 38% of the observed data and 44.2% of the Exponential Growth Regression data fits the model. These results tell us how important is the rainfall effect alone over the male elephants sightings.

Fig. 7B, shows a similar pattern as with males, all three regression models used significantly supported that with higher values of rainfall, sightings of females were lower: the Linear Regression model (R= 0.518; R^2= 0.269; F= 30.134; p-value< 0.001) represented by the equation model [Y= -0.1058*X + 12.3413], the Exponential Growth model (R= 0.465; R^2= 0.216 F= 22.605; p-value< 0.001) defined by [Y= exp(2.4804 + -0.0135*X)], and the Poisson Regression (X^2=24.433; B= -0.012; df=1; p-value< 0.001).

In this case, our Linear model for female herds explains up to a 26.9% of the observed data and 21.6% of the Exponential Growth Regression data fits the model.

- ***Adult males forming groups against adults travelling alone comparison (H2).***

More adults males (>26 years) were observed travelling in group when using "elephant highways" (60.34%), and the difference was considered significant by the Chi square Test (X^2=473.750; df=1; p-value< 0.001; Fig. 8).

- ***Adult male proportion within groups compared to the subadult proportion (H3).***

To test if male elephant groups are predominantly made up of adults (>26 years), we assessed a Binominal test to the binary dataset (Fig. 9): Groups with an adult proportion of >0.5 (1) and an adult proportion of ≤0.5 (0).

The adult male proportion within groups was greater in 41.66% of the studied cases (3651 datapoints). The results were significant and were the opposite from what we hypothesised (X^2=116.917; df=1; p-value< 0.001), consequently, younger males (<26 years) were predominant in the majority of cases (58.34%).

- ***Comparison between the dry and wet season male associations (H4).***

The Chi-Square Test was considered and complemented with other similar tests, significant differences between the dry and wet season were found (X^2= 58.236; df= 1; p-value< 0.001). During the dry season 25.07% of the males were forming groups, in contrast, during the wet season up to 21.76% of males were found in a group. The mean percentage of males forming groups without seasonality was 23.70%. The significant differences found are the contrary of our hypothesis, since during the dry season males formed more groups.

- Most common male elephant groups

We analysed the male grouping combinations of our dataset, considering group size and age: 90% of the groups found have group sizes between 2, 3 and 4 male elephants. Groups consisting of 2 males is the size group most found, and out of these male pairs, the most abundant combination are age mixed groups (Table 1. 1103 pairs mixed male groups). Groups formed by 2 adults have shown great importance too, with 802 pairs of adult males.

The second most common size group are groups consisting of 3 males, from which 616 are groups with at least one adult male. The least found combination out of the 3 male groups is the 3 subadult groups. Out of the groups made up by 4 male members, the common combinations found have 2 or 3 adult males.

- ***Cropping season vs. non-cropping season non-parametric analyses (H5).***

Data from cameras EfA02, EfA05, EfA06, EfA07, EfA08 and EfA09 (cameras with human settlements / crop fields nearby, < 20km), were used to answer our last hypothesis, which was if elephants use more the “elephant highways” close to crop fields and human settlements during the cropping season. We assessed a median comparison and significant differences were detected. During the cropping season months, the median of daily male elephant sightings recorded was of 21 individuals, whereas the non-cropping season median was of 19 males (X^2= 10.637; df= 1; p-value= 0.001; Fig. 10).

- **<u>Cropping season versus non-cropping season night activity using 2015 CT data</u>**

Again, the median for the night-time cropping season period is significantly superior (P= 5,106; df= 1; p-value= 0.033; Fig. 11), night-time male elephant sightings median was of 8 individuals, whereas the non-cropping season median was of 6 males.

Discussion

Elephant populations are changing their home ranges and migration patterns due to climate change and anthropogenic pressure (Advani 2014). Given the data we had from EfA observations and from spoor in the park, it was expected that more females had started using the MPNP over the study period (EfA- unpublished data). Female herd activity showed an annual increase of 6.39%, although expected, the value obtained is high and it is necessary to mention that the daily recordings of female herds in 2014 were low, maybe overestimating a bit the growth. Even though there's an increase, 30% of the days had 0 sightings, which may indicate that females herds have not yet settled permanently. The MPNP is used more as a passing area, which is gaining importance and therefore more female activity has been recorded. Our male elephant activity dataset had an annual increase of 4.26%. Since the Boteti River resurged (2009), male elephants, which are higher risk takers, were more drawn to the area at first, and then female herds started appearing, looking for safe and rest areas during migrations and/or to stay temporally. The "elephant repopulation" theory, support that male elephants repopulate an area first, and ends when stable populations of both sex settle (EfA- unpublished data). Not every repopulation process ends with both sexes stable populations, that only happens if the habitat covers female and male needs, if this is not the case, it can result in male areas or female breeding spots. Although the elephant populations are transiently, the increases of males and female herds activity reported in this project are consistent with the repopulation process described.

Significant differences were found between the dry and wet season distribution and medians of the male daily sightings, with higher values during the dry season. Therefore, results are very coherent, since the area has the Boteti river and during dry periods is what elephants look for. However female herds, not only choose an area for its resources and water presence, it has to be suitable for their young individuals, which can be more vulnerable and even predated. Also, females need high quality food, which the MPNP can lack to provide, whereas males can eat more poor nutrimental food (K. Evans, 2006; K. Evans and Harris, 2012). Since female herds need to be more sure when moving into a new area and also numbers are still very low in comparison to the male presence, this could be some of the reasons why seasonality wasn't found.

In both cases, the male and female herds datasets, variance was higher during the wet season, which could mean that the elephants are more disperse since there's more food and water available. This has been reported in projects like Ashiagbor and Danquah (2017).

When checking the rainfall effect, we obtained significant results that showed how male and female elephant activity decreased when the rainfall increased (negative correlation). The male elephant rainfall models used explained 38-44.2% of the observed data, and the rest could be explained by other factors (Mole and others 2016), like, temperature (cold months= less river usage), cloudy weather, wind conditions (elephants can't hear well), cropping season, etc. Female herds rainfall regression explained less of the observed data, 21.6-26.9%, meaning that they probably have more factors that come into play (like predators, humans, competition for resources, safe resting areas…).

When analysing the social aspect of males, we found that more adults (+26 years) were observed travelling in groups (60.34%). Even though there's preference to travelling within a group led by adult males, these results don't necessarily mean that adult males are the ones looking for these temporal bond groups, in fact, other studies Murphy and others (2020), show that the younger individuals are usually the ones following the adults, since those teach them and transmit intergenerational knowledge. To support this idea, projects like, Allen and others (2020), have studied the leader figure in male groups and concluded that older males tend to be the centre of these social networks.

As well, we found that male elephant groups are predominantly made up of younger males (<26 years), in fact, groups with an adult male proportion of <0.5 represented a 58.34% of the studied groups. Since 22% (3865/1729) of the male elephants were adult males (>26 years) compared to the 78% of younger individuals, it would have been difficult that the adult proportion when grouping would have been greater than the young male portion, but even so, the results obtained support the leadership role theory of older males. These proportions are very similar to the ones found in Gajah, 2008.

During the dry season, more males were found forming groups (25.07%) when utilising the “elephant highways” in comparison to the wet season (21.76%). Even though we hypothesised the opposite to happen, we were aware of projects like, Murphy and others, 2012; O’Connell-Rodwell and others, 2011, which determined that male elephants tend to form more groups during the dry season to be more efficient when finding limited food and water. When environmental conditions get dry and/or during drought years, competition between males appears, but intra-specific conflicts are usually avoided, thanks to the fact that, linear dominance hierarchy (based on their age) becomes stronger (O’Connell-Rodwell and others, 2011). During the wet season less elephant males formed groups, supporting the idea that males use groups to cope with periods of limitations on water and food.

More elephant activity was found on the “elephant highways” during the cropping season, results showed that the median during the cropping season months was significantly higher (21 individuals/day) than during the non-cropping season period (19 individuals/day).

The male night-time activity comparison of 2015 found significant differences between the 8 individuals median during the cropping season night-time and of 6 individuals during the non-cropping season night-time. Even though we were not trying to link finding more elephant activity directly to crop raiding, we still believe that it’s not by chance that our findings found more elephant activity at night-time during the cropping season.

This project recommends a further investigation relating to the current human-elephant conflict in the area to minimize the impact on local communities. Also, stronger measures related to trophy hunting and illegal hunting to prevent/stop the killing of elephants are needed, specially the targeted older males, since they are much more important that initially thought.

List of figure captions:

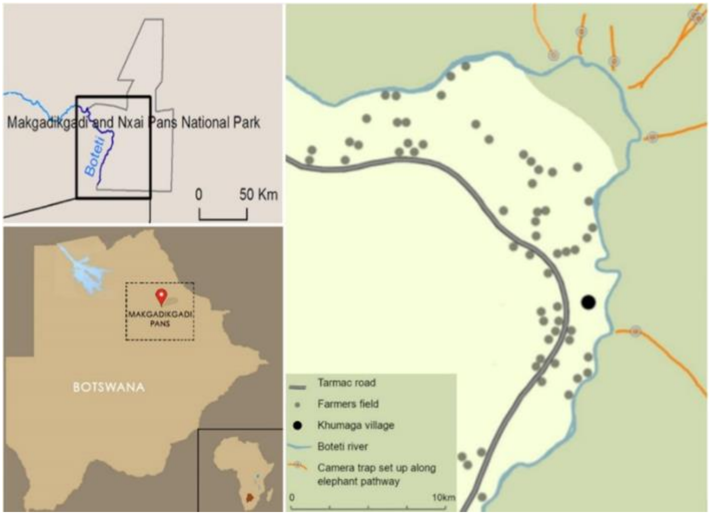


Fig 1. Map of Makgadikgadi Pans National Park, Botswana: shows the study area, Boteti River, roads, Khumaga village, protected land (green) and the camera traps locations (Allen and others, 2020).

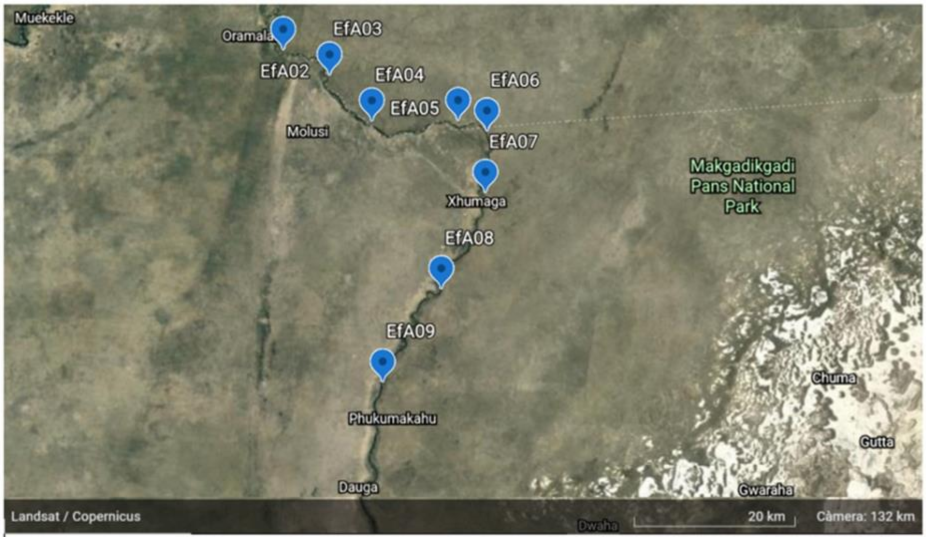


Fig 2. Map of the study area with the locations of the CT along the "elephant highways" leading to and from the Boteti River and the local communities on the river's western bank, like the Khumaga village.

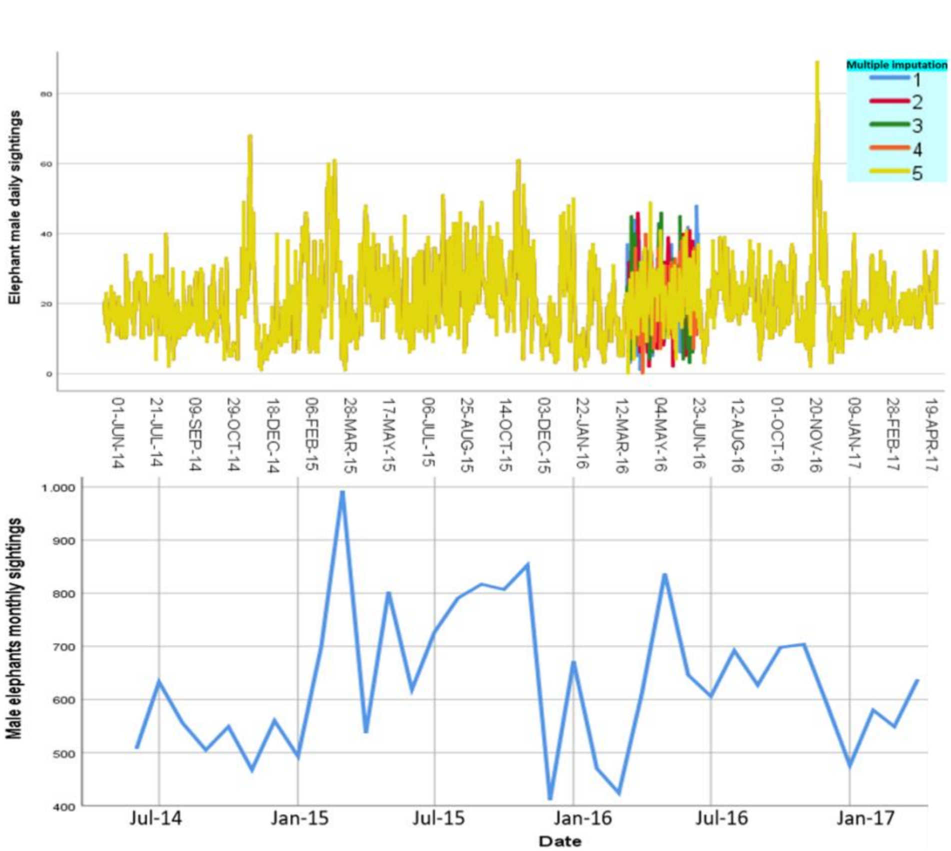


Fig 3A. A preliminary temporal series representation of the daily and monthly sightings of the male dataset. 2015 drought can be appreciated with the increment of male sightings that period, since camera traps were located close to the Boteti River.

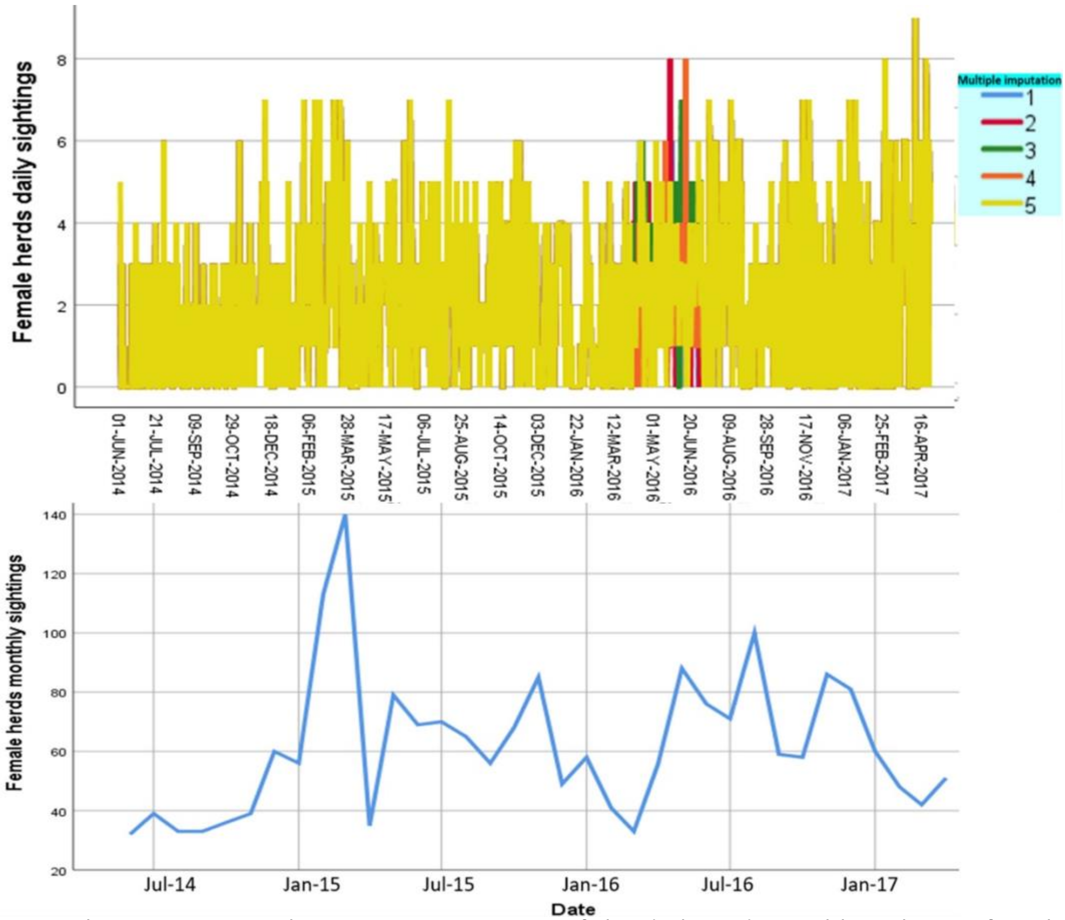


Fig 3B. A prelaminar temporal series representation of the daily and monthly sightings female herds dataset. 30% of the dataset were days with 0 female herds sighted.

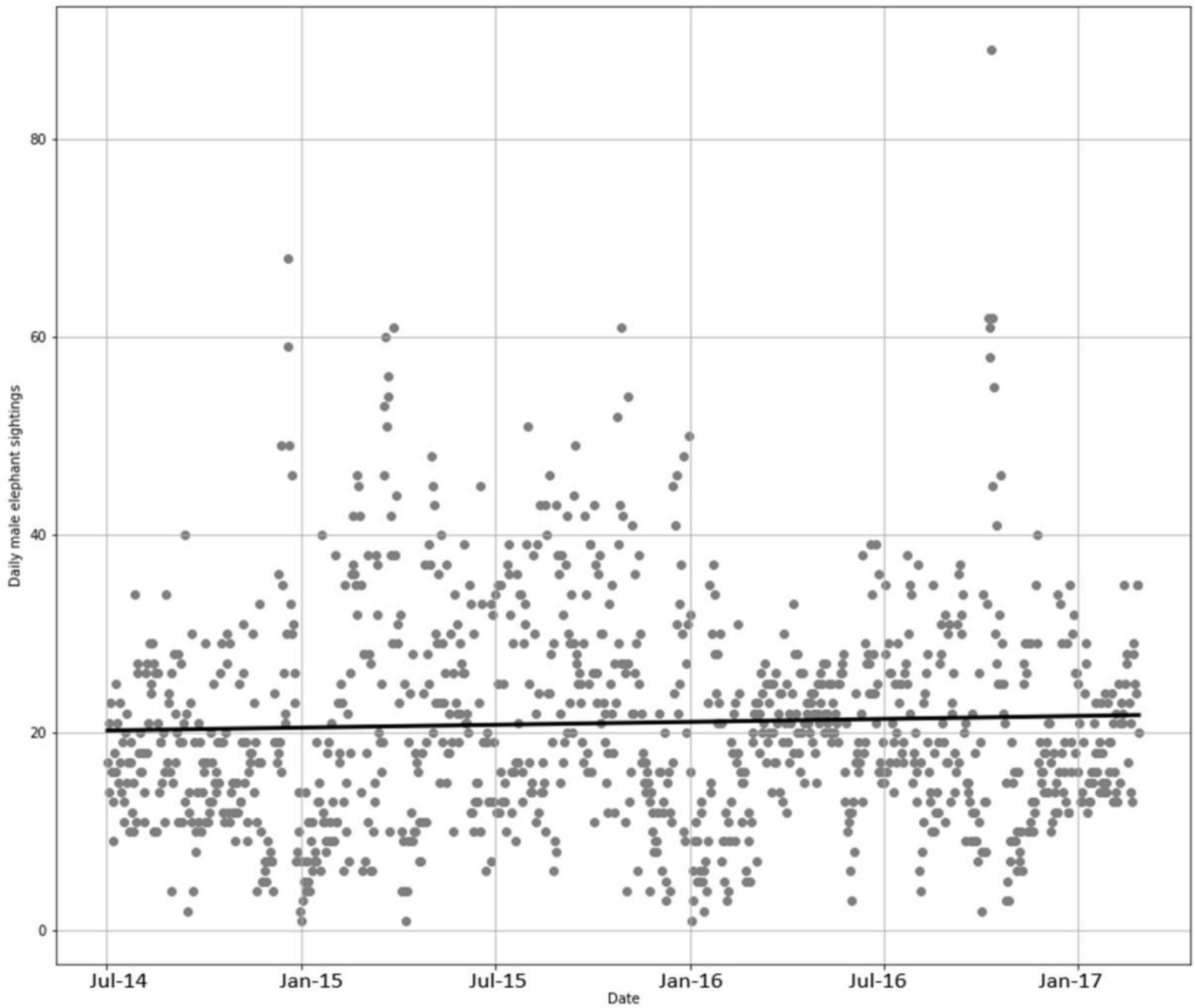


Fig 4A. The male daily sightings dataset was used to create this graphic showing a Poisson regression function representing the growth using Python; Y= e((6,99E-5*X) + 3,007).

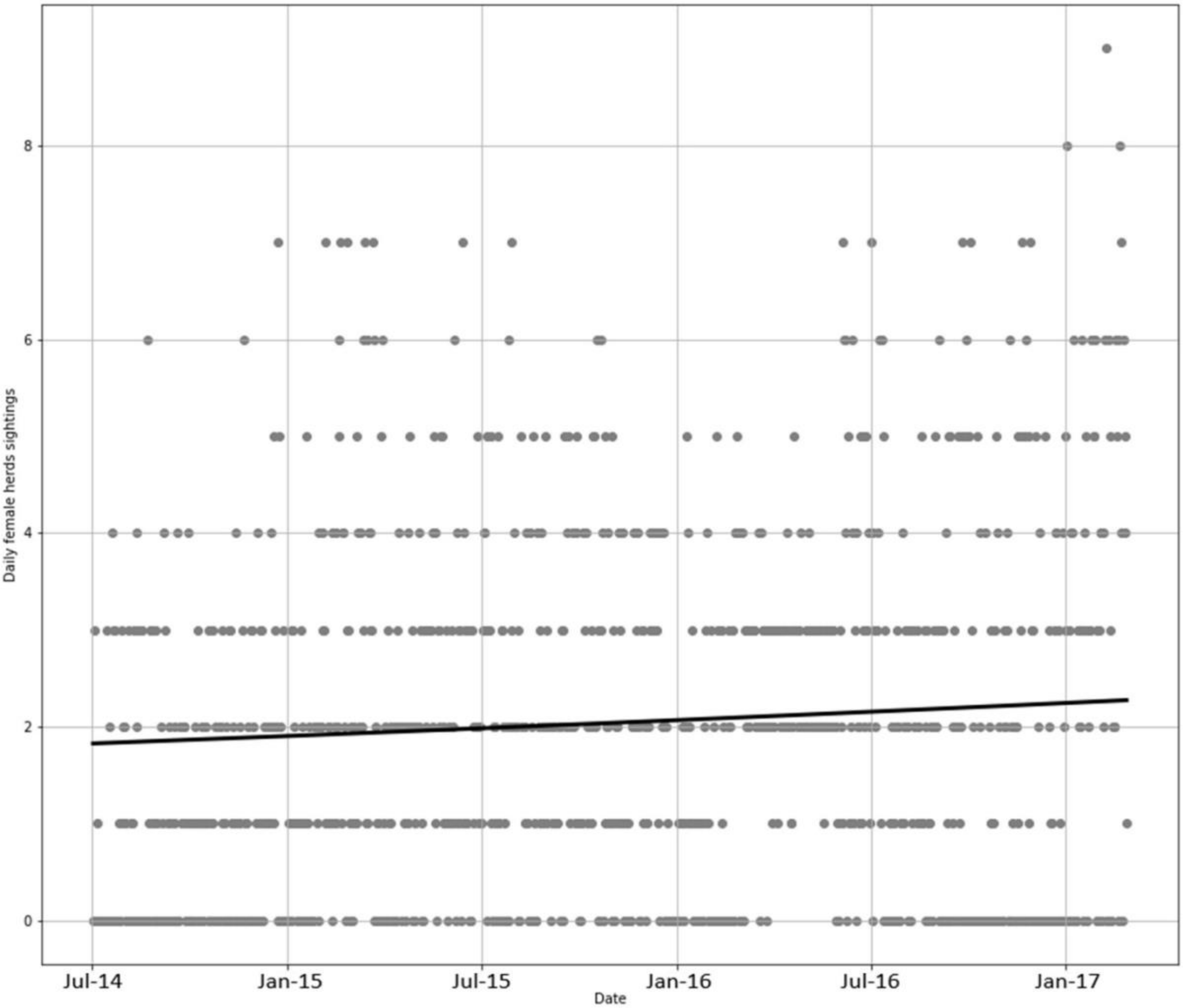
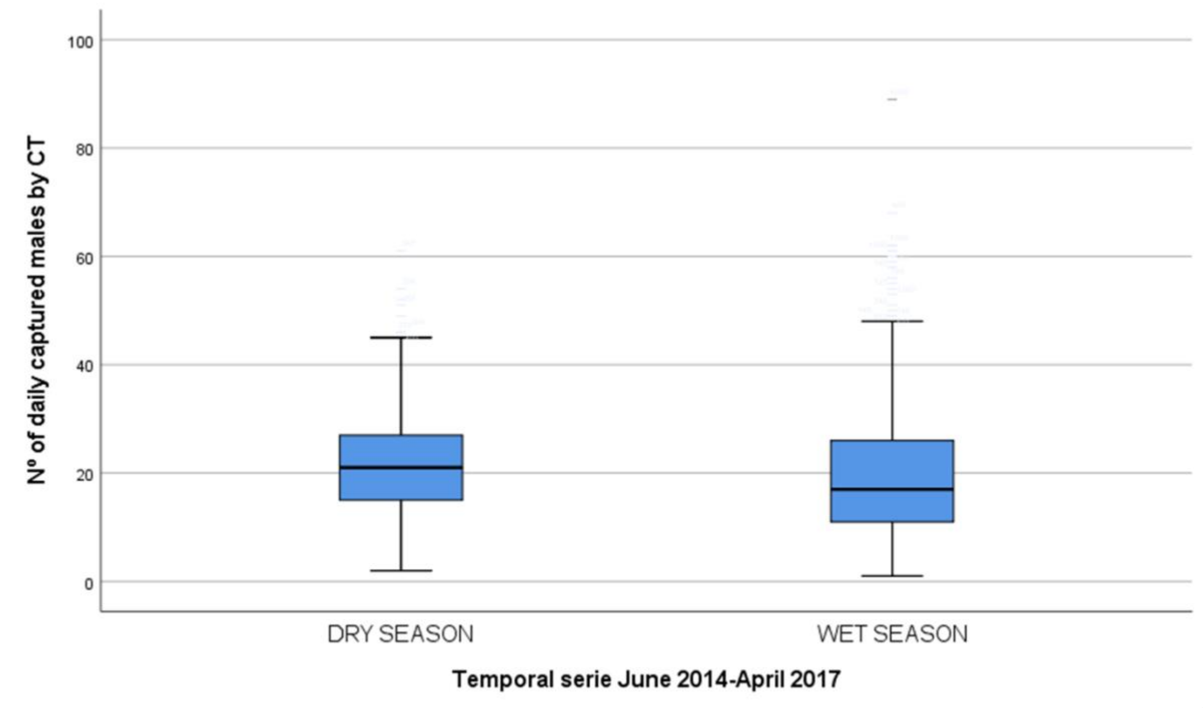


Fig 4B. The female herds daily sightings dataset was used to create this graphic showing a Poisson regression function representing the growth using Python; Y=exp ((0.000206*X) + 0.603).



Percentiles

	Season June 2014-April 2015	Percentiles 5	10	25	50	75	90	95
Nº of daily captured males by CT	DRY SEAS	10,00	11,00	14,00	19,00	24,00	29,00	30,80
	WET SEAS	4,00	6,00	9,00	17,00	30,50	42,00	49,00

Fig 5A. Male activity comparison between all the wet and dry season months. Dry season data presents a significantly higher median (21). Wet season data has a higher variance, and the top 10% of the daily sightings have higher values than the dry season ones.

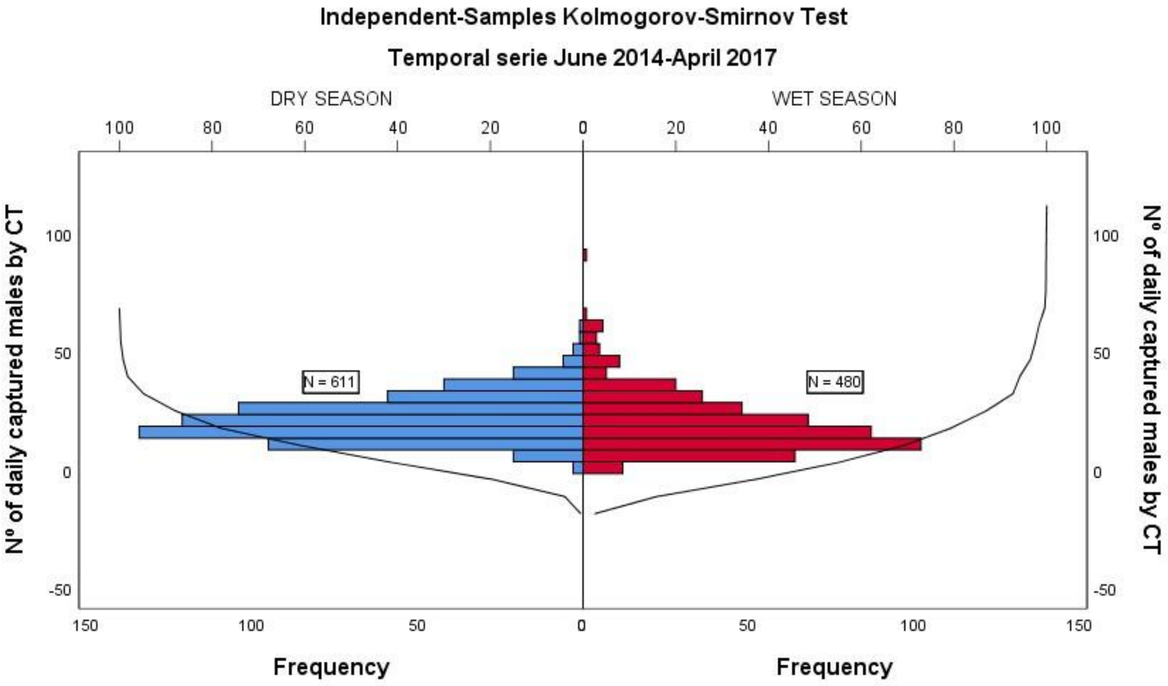
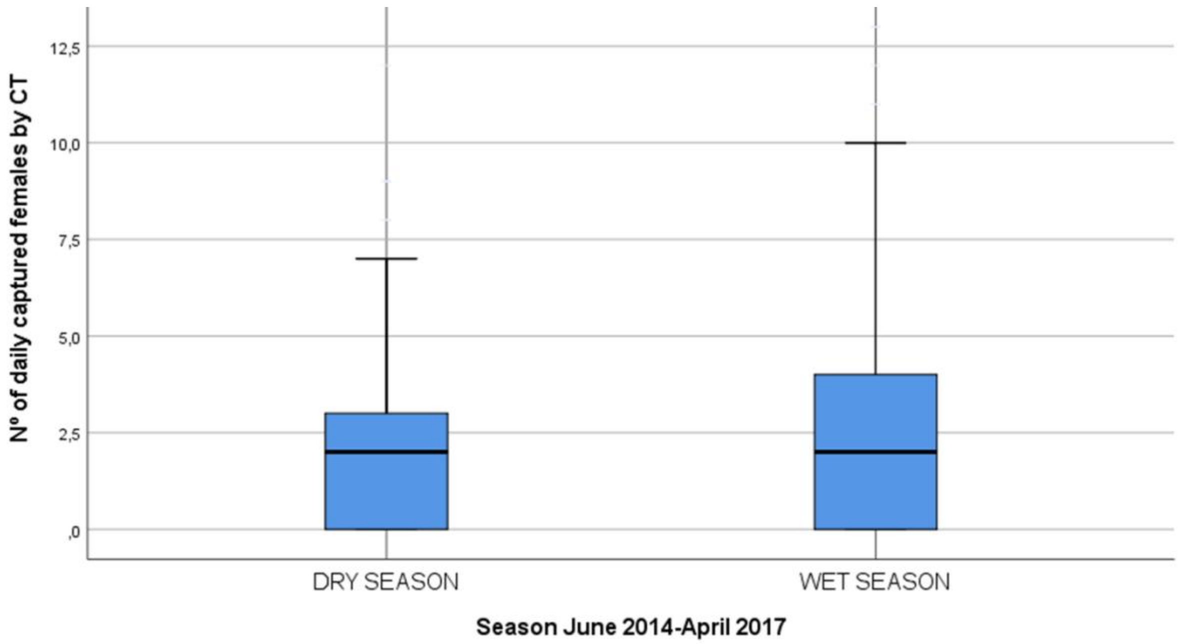


Fig 5B. Comparison of the male sightings cumulative distribution between the dry and wet season.



Percentiles

	Season June 2014-April 2017	Percentiles 5	10	25	50	75	90	95
Nº of daily captured females by CT	DRY SEAS	,00	,00	,00	2,00	3,00	5,00	6,00
	WET SEAS	,00	,00	,00	2,00	4,00	5,40	7,00

Fig 6A. Female herds activity comparison between all the wet and dry season months. Dry and wet season data present the same median (2). Wet season data has a higher variance, and the 3rd percentile shows higher values of daily sightings than the dry season ones.

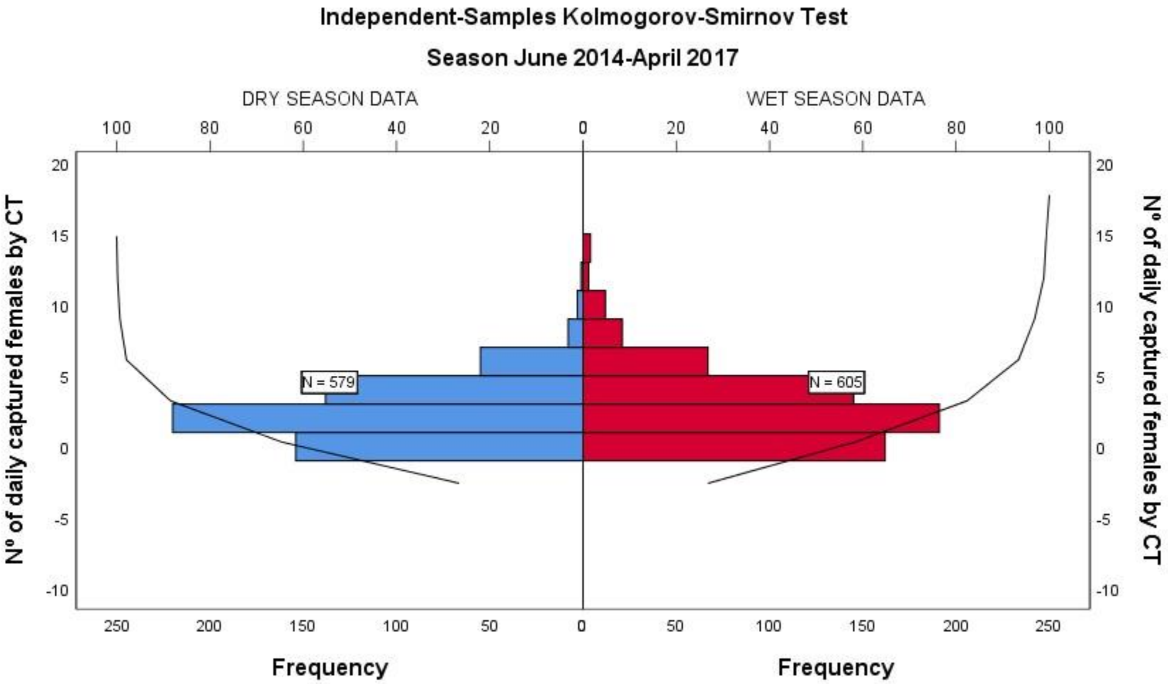


Fig 6B. Comparison of the female herds daily sightings cumulative distributions, between the dry and wet season.

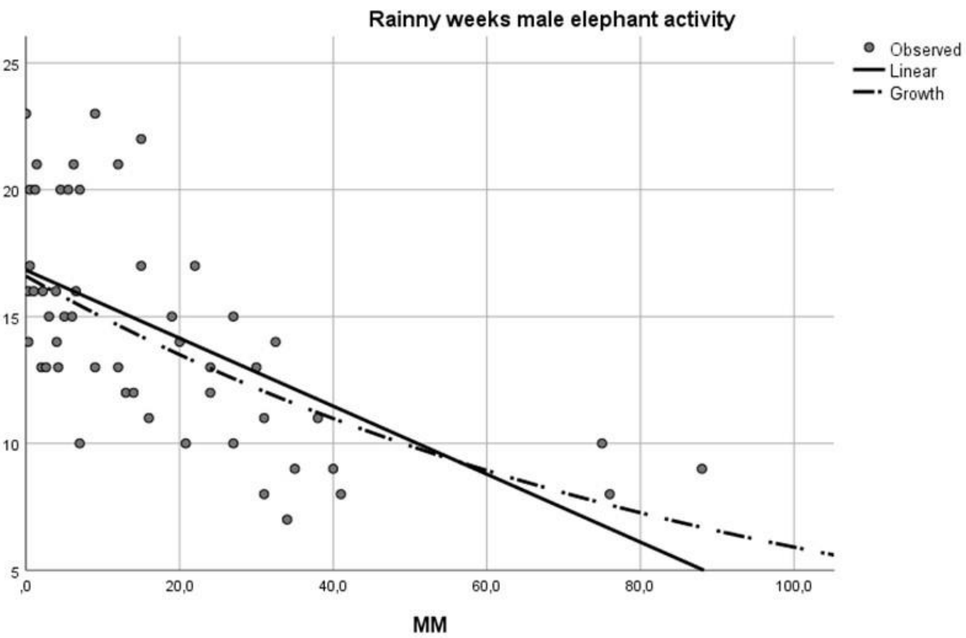


Fig 7A. Each datapoint represents the male activity recorded during the 5 days after rainfall was registered (rainy day included). Linear regression equation [Y= -0.134*X + 16.826] *and Exponential Growth* [Y= exp(2.8091 + -0.0103*X)] *are represented.*

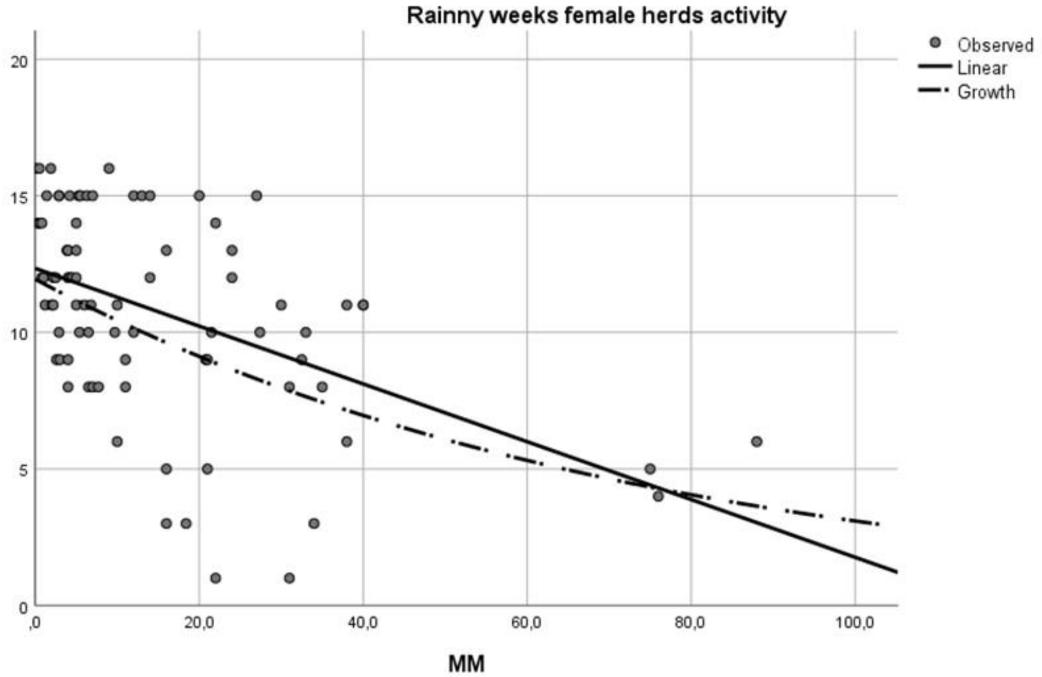


Fig 7B. Each datapoint represents the female activity recorded during the 5 days after rainfall was registered (rainy day included). Linear regression equation [Y= -0.1058*X + 12.3413] *and Exponential Growth* [Y= exp(2.4804 + -0.0135*X)] *are represented*.

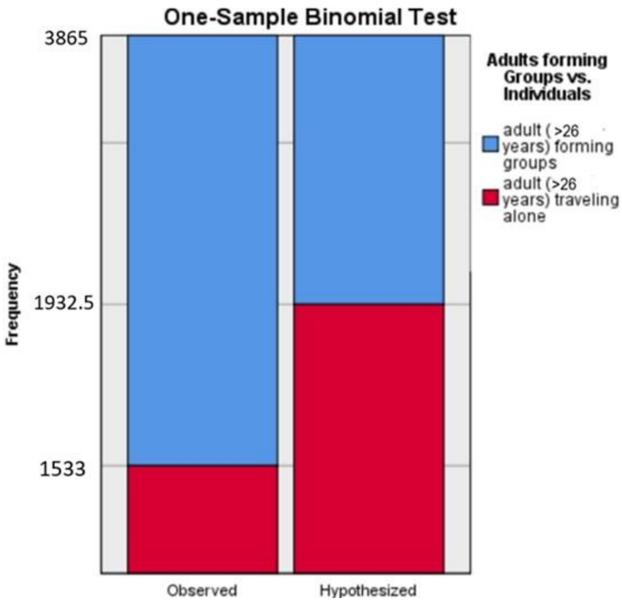


Fig 8. Additionally, a Binominal test was performed: Z=21; St. Error=52.628; p-value< 0.001. *The bar plot represents male adults forming groups to travel vs adults travelling alone, and show how more adult males were found travelling in groups.*

Proportion of adults within groups (over 0.5=1)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	2130	58,3	58,3	58,3
	1	1521	41,7	41,7	100,0
	Total	3651	100,0	100,0	

Hypothesis Test Summary

Null Hypothesis	Test	Sig.	Decision
The categories of Proportion of adults within groups (over 0.5=1) occur with equal probabilities.	One-Sample Chi-Square Test	,000	Reject the null hypothesis.
The categories defined by Proportion of adults within groups (over 0.5=1) = >0.5 and <0.5 occur with probabilities ,500 and ,500.	One-Sample Binomial Test	,000	Reject the null hypothesis.

Fig 9. Chi Square and Binominal test results were significant, and show how the young male proportion is predominant in 2130 groups out of the 3651 studied cases (58.3%).

		Total											
		2	3	4	5	6	7	8	9	10	11	12	13
		Count	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
adult (21-36+ years)	0	552	116	26	6	5	1	0	0	0	0	0	0
	1	1103	273	83	22	10	4	4	2	0	0	0	0
	2	802	343	113	51	17	3	1	0	0	0	0	0
	3	0	213	103	49	22	12	3	2	3	0	1	1
	4	0	0	56	40	28	14	5	3	0	0	0	0
	5	0	0	0	16	13	8	6	3	0	0	0	1
	6	0	0	0	0	5	7	7	3	2	1	1	0
	7	0	0	0	0	0	1	5	1	4	1	0	0
	8	0	0	0	0	0	0	0	3	0	2	0	0
	9	0	0	0	0	0	0	0	0	0	1	1	1

Table 1. Cross table analysis with group size and age as variables, giving all the combinations found in our dataset.

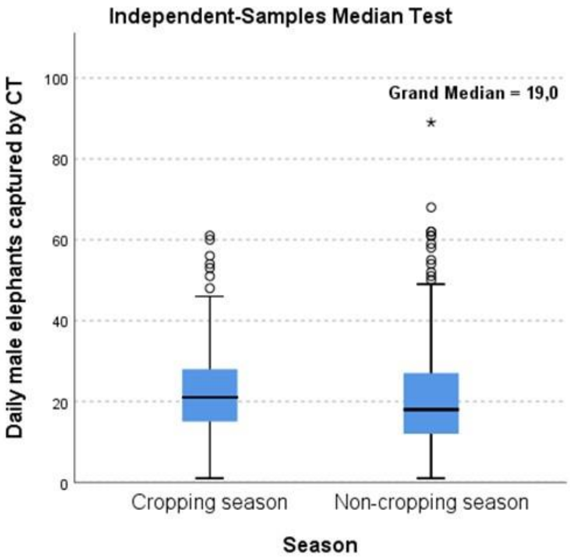


Fig 10. Crop season vs non-crop season Box-plot analysis. A significantly higher median of daily male sightings was recorded during the crop season (21) in comparison to the non-crop season period (19).

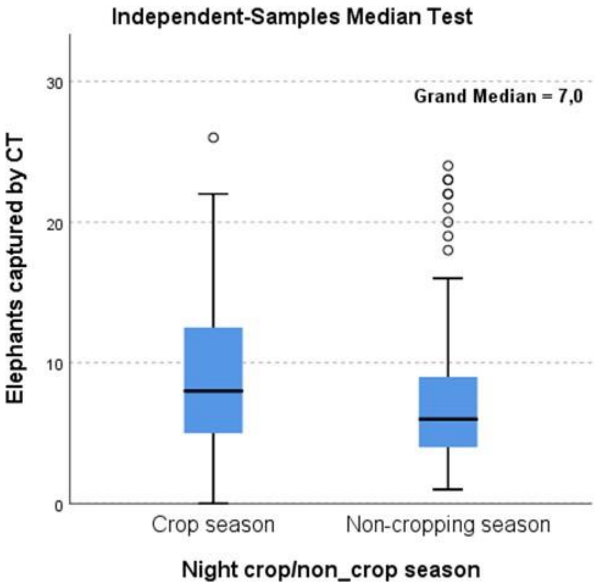


Fig 11. Crop season vs non-crop season night-time male activity Box-plot analysis (2015). A significantly higher median was recorded during the crop season (8) in comparison to the non-crop season (6).

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