Seasonal variation in giraffe population density and abundance in the Tsavo landscape, Kenya.

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ABSTRACT

The giraffe population is thought to vary seasonally in the Tsavo landscape of Kenya but little data exists to establish if there indeed exists any variability. This study examined the impact of seasonal variation on the giraffe population in the Tsavo landscape. We conducted road transect counts and found 2,683 and 3,295 giraffes during the wet and dry seasons, with mean KAI and density of 0.19±0.01 and 1.20 ± 0.435/km^2 respectively. Giraffe population did not vary significantly, but age and sex distribution differed significantly between seasons. The parks had more giraffes during the wet season compared to the dry season, while the reverse was true for Rombo and Taita ranches. No giraffes were sighted in South Kitui National Reserve.

INTRODUCTION

Seasonality is critical in natural systems (Williams et al., 2017), and has played a significant part in the global patterns in biodiversity (Varpe, 2017; Williams et al., 2017). It has also shaped the evolution of many physiological and behavioral adaptations, seasons directly determine resource patterns and consequently influence the distribution of species (Kentie *et al*., 2018; Mancinelli *et al*., 2019; Zeller *et al*., 2019; Avgar, Betini & Fryxell, 2020 Berta Aneseyee *et al*., 2020). For instance, water is a key limiting factor for many species in Africa's arid and semi-arid habitats (Western, 1975; Redfern *et al*., 2005; Obari, 2014; Naidoo *et al*., 2020). Quantifying seasonal variation in the distribution, abundance, and density of animal populations is fundamental to understanding their ecology (Matthiopoulos, Field & MacLeod, 2019; Osorio-Olvera, Soberón, & Falconi, 2019).

The giraffe belongs to the family giraffidae, consisting of the genera *Giraffa* and *Okapi* (Merceron, Colyn, & Geraads, 2018; Ramsauer *et al.,* 2018). The former is the more abundant and is made up of one species, *Giraffa camelopardalis,* that has nine sub-species (Muller *et al.*, 2018). These inhabit a range of arid and semi-arid savannahs south of the Sahara (O'Connor *et al*., 2019).The Masai giraffe (*Giraffa camelopardalis tippelskirchi*) range declined by 4.7% between 2016 and 2019, with 59% occupying protected areas (O'connor *et al*., 2019) which lack enough size to independently support viable populations or accommodate their huge-ranging patterns (Okello *et al*., 2015; O'connor *et al*., 2019). Human activities have greatly compromised the viability of non-protected areas as giraffe habitats, migratory corridors, and dispersal areas (Ogutu *et al*., 2011; O'connor *et al*., 2019). The Tsavo population has experienced a precipitous drop since the mid-980s (Muller *et al*., 2018), reflecting the overall trend for the species and habitat range across Africa (O'connor *et al*., 2019). Declines have been attributed to extrinsic threats such as poaching, habitat loss, infrastructural development, climate change and interspecific competition (KWS, 2018). Intrinsic threats include inbreeding, disease, and intraspecific competition. These were among the many factors that led to the listing of masai giraffes as endangered by the IUCN (Bolger *et al.,* 2019).

Wet and dry season giraffe movement between and across heterogenous landscapes is attributed to differences in forage abundance, vegetation productivity, and the rate of plant compensatory growth (Deacon & Smit, 2017; Okello *et al*., 2015; Obari, 2009). Giraffes move to riverine habitats and beyond protected areas using specific corridors (Obari, 2014; Okello *et al*., 2015, Leuthold, 1978). Comparing wet season and dry season rainfall patterns can therefore help explain how ecological factors such as competition with livestock shapes the dynamics between parks and adjacent ranches or human dominated habitats. Understanding seasonal variation in animal abundance and density is important, especially where prolonged dry conditions can be expected to exert pressure on population dynamics and ultimately shape an animal's physiology, ecology and behavior (Doody *et al*. 2015). Here, we quantified seasonal variability in giraffe population density and abundance in the Tsavo landscape Kenya, using road transect counts to estimate variation across seasons. We discuss the implications of this research for the conservation of masai giraffe in southern Kenya and other endangered giraffe subspecies in heterogenous landscapes across Africa.

METHODS

Study Area

We positioned this study in the Tsavo landscape, the largest conservation complex in Kenya covering more than 43,000 km^2 and including a matrix of national parks, reserves, ranches, conservancies, community livestock, and farming areas. The region is characterized by vast savannah plains that are occasionally punctuated by hills and inselbergs which are responsible for the elevation range of between 400 meters and 1,700 meters above sea level. This difference explains the variation in precipitation and vegetation throughout the landscape (KWS, 2008; Mukeka, 2010). *Vachiella-Commiphora* and *Senegalia-Commiphora* associations account for the highest percentage of the woody plant species found in the landscape with the density of shrubs and trees varying seasonally and spatially (KWS, 2008). The landscape has one of the highest diversities of fauna in Kenya and also harbors one of the largest populations of free-ranging African elephants (Loxodonta Africana) (Blanc *et al*., 2007; Omondi *et al*., 2008). Other notable large mammals include; the lion (Panthera leo), leopard (*Panthera pardus pardus*), buffalo (Syncerus caffer), hippo (*Hippopotamus amphibius*), and black rhino (*Diceros bicornis*) (Mukeka, 2010). Galana and Tsavo are the two permanent rivers that flow through the landscape, amidst many seasonal rivers and artificial water sources. Mean annual rainfall ranges between 200 and 500 mm (Mukeka, 2010). Closed canopy forests along riverbanks are among the areas with dense vegetation all year round (Mukeka, 2010; KWS, 2018).

Data Collection

Giraffe Population and Density

We divided the study area into five geographic subregions based on their management and protection levels. The subregions were; Tsavo East National Park (TENP), Tsavo West National Park (TWNP), Rombo Group Ranch (RGR), Taita ranches and South Kitui National Reserve (SKNR). TENP and TWNP are protected areas managed by the national government, RGR, and Taita ranches, and SKNR are non-protected areas. Replicate surveys were conducted in each subregion during the wet season (October - December 2020) and dry season (Jan - March 2021), driving along established roads and tracks at an average speed of 30km/hr. We used 51 road transects each averaging 31.09 km, the roads were distributed throughout the landscape (Fig. 1) and covered a total distance of 1,574 km. During each survey undertaken between 6:00 am and 10:00 am, two observers searched and recorded giraffes on both sides while noting those located within a distance of 1,000 meters. We assumed that giraffes did not move from already surveyed areas to non-surveyed areas. Individual giraffes or herds were located visually and counted using a pair of binoculars. Upon each sighting, the Global Positioning System (GPS) coordinates, angle relative to the direction of motion, and distance from the observer were measured using a range finder and recorded using the cyber tracker mobile application (Ansell and Koenig, 2011). In the case of curved roads, we used the tangent of the curve to establish the distance between the observers and the sighted animal. Collected data were sorted using the Spatial Monitoring and Reporting Tool (SMART) software (SMART, 2017). The Kilometric Abundance Index (KAI) was calculated from sample transect counts. KAI measures the proportion of total individuals (or signals of presence) seen along a transect to the total length that the transect covered at each site (Preatoni *et al*., 2012). Giraffe counts were also pooled together and modeled into population and density estimates using Distance 7.3 software (Thomas *et al.*, 2010), which includes a detection function that replicates the decline in animal detectability with increasing distance from the observer (Buckland *et al*., 2001). It utilizes a probability density function:

$$\hat{D} = n/2wL\hat{P}_a$$

where *D* is the estimator of wildlife density; *n* is the total number of counted wildlife from a line of *L* length within *w* distance from the line. For this study, *L* was the road transect length while *w* was the distance from the observer to the sighted animal. *P* is the probability of detection for an object within an area *a*. *Pa* can be expressed as below:

$$P_a = \frac{\int_0^w g(x)dx}{w}$$

where *g(x)* is detection function in relation to *x* length which is the distance between the line and the object. Distance sampling assumes that; there are no errors in measuring distance, probability of detecting animals along a transect is 1 and animals do not move (Iijima, 2020).

Sex and age structure

Each giraffe sighted was categorized into its respective sex (male or female) and age class (adult, subadult, and juvenile) based on external morphology, body size and hair colour in accordance with previous giraffe research (e.g., Fennessy, 2004; D'haen *et al*., 2019). Sex and age class identification were determined using external genitalia, body size, pelage, and presence or absence of mammary glands (D'haen *et al*., 2019). Following Muller, Cuthill and Harris, (2022), adults were individuals aged 4+ years, subadults were 12 months or more but <4 years, and juveniles were <12 months.

RESULTS

We recorded 295 giraffes along the transects in the dry season and 327 in the wet season. Modelling results estimated a population of 5,978 giraffes, with 2,683 and 3,295 individuals in the wet and dry seasons respectively, with a mean of 2,971±288 (Table 1; Fig 1). Giraffe population did not vary significantly during the two seasons ($\chi^2 = 1.6463$, df = 1, $P > 0.05$). We established a mean KAI of 0.19 ± 0.01 and a mean density of 1.20 ± 0.435/km^2. Of the individuals identified, 160 giraffes were male and 297 females, while 162 could not be sexed. Male to female sex ratio was established at 1.00:1.86. Young giraffe comprised (13.40%, n = 83), and adults (86.57%, n = 535), resulting in a ratio of 1.00:6.46 (Table 2). Age distribution ($\chi^2 = 0.09$, df = 1, $P > 0.05$) and sex structure ($\chi^2 = 0.001$, df = 1, $P > 0.05$) were not significantly different between the wet and dry seasons.

Density differed among seasons in all sites except SKNR which had no giraffe sightings - TWNP ($\chi^2 = 18.19$, df = 1, $P < 0.05$), TENP ($\chi^2 = 500.25$, df = 1, $P < 0.05$), Taita ranches ($\chi^2 = 60.16$, df = 1, $P < 0.05$) and RGR ($\chi^2 = 297.79$, df = 1, $P < 0.05$). TWNP and TENP had an estimated population of 1,622 and 1,445 in the wet season respectively, and 1388 and 467 in the dry seasons respectively. Taita ranches had 114 giraffes in the wet season and 265 in the dry season, while RGR had 114 giraffes during the wet season and 565 giraffes during the dry season.

DISCUSSION

Most protected areas are also core wildlife habitats and are crucial in building and maintaining wildlife populations (Okello *et al*., 2015). This study observed that though giraffe population did not vary significantly between seasons, they were more abundant in the protected areas. Masai giraffe absence in SKNR was attributed to the destruction of habitat, poaching, and overgrazing. The findings agree with a previous study in southern Kenya where the giraffe population was higher inside protected areas as compared to outside protected areas (Obari, 2014; Okello *et al*., 2015).

We found that the giraffe population in the Tsavo landscape was female skewed with a 1.00:1.63 male-to-female sex ratio. This differed significantly from the expected 1:1 which we attribute to imbalances in adult and subadult mortality (Marealle *et al*., 2010; Kappeler, 2017). Foster, (1966) and Fennessy, (2004) established that giraffe populations exhibit 1:1 male-to-female sex ratios in Nairobi National Park and the desert-dwelling giraffe of Namibia, respectively. However, sex ratios may vary in some wild populations due to skewed juvenile, sub-adult and adult mortality (Marealle et al., 2010; Kappeler, 2017). Female-skewed sex ratios may increase the viability and reproductive fitness of a population (D'haen et al., 2019; Folt et al., 2021). Poaching is one of the major issues affecting giraffe conservation in Kenya (KWS 2008). Though our study did not focus on poaching, we recorded numerous giraffe poaching incidences, especially in the non-protected areas. Similar to D'haen et al., (2019) and Marealle et al., (2010), on giraffe populations and poaching in Garamba National Park and the Serengeti ecosystem respectively, we suggest that the female-skewed sex ratio could be a result of poaching that mostly targets adult males.

Giraffe form very loose social bonds and have inconsistent patterns of relationships (Wolf *et a*l., 2018; Ferres *et al*., 2021) which are influenced by seasonal resource variability and other factors (Wolf *et al*., 2018; Bond *et al*., 2019). Furthermore, giraffes exhibit sexual differences in foraging and forage requirements in different seasons (Mramba *et al*.,2017). Though sex and age did not vary significantly between the wet and dry seasons, we observed seasonal differences in masai giraffe sex and age structure. These were attributed to sex and age-based niche partitioning of habitat and sexually divergent foraging strategies (O'Connor *et al*., 2015; Bond *et al*., 2019; Brown and Bolger 2020).

Forage and water availability influence productivity in arid and semi-arid habitats and, correspondingly, wildlife abundance, density, and distribution (Groom & Western, 2013; Rich et al., 2019). Past research in the Kenya-Tanzania borderland region revealed that giraffes were more abundant in protected areas during the wet season, as compared to the dry season (Okello *et al*., 2015; Deacon & Smit,2017). Similarly, we established that seasonal variation greatly affected giraffe distribution, with TWNP and TENP having high giraffe abundance in the wet season compared to the dry season. RGR and Taita ranches had higher giraffe abundance in the dry season compared to the wet season. High giraffe abundance in the protected areas during the wet season was attributed to the presence of pasture and seasonal watering points. On the other hand, low giraffe abundance in protected areas was linked to the migration outside protected areas in search of water and pasture during the dry season. RGR, Taita ranches, Kuku ranch , Cyulu National Park and Kulalu ranch are potential TENP and TWNP giraffe dispersal areas during the dry season.

CONFLICTS OF INTEREST

Authors declare that they have no competing interests.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from African Wildlife Foundation. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors with the permission of the African Wildlife Foundation.

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TABLES

Table 1: Predicted Masai giraffe (*Giraffa camelopardalis tippelskirchi*) population and density estimates in the wet and dry seasons in the Tsavo landscape.

	Individuals Observed	Population Estimate	Density/Km^2	Kilometric Index (KAI)	Abundance
Wet Season	327	3,259	0.76	0.2	
Dry Season	295	2,683	1.63	0.18	
Mean + SE	311±16	2,971±288	1.20±0.435	0.19±0.01	

Table 2: Masai giraffe (*Giraffa camelopardalis tippelskirchi*) age and sex structure in the wet and dry seasons in Tsavo landscape.

	Wet Season	Dry Season	Mean± SE
Adult females	149	136	142.50±6.5
Adult males	68	68	68.00±0.00
Adults unknown	65	49	57.00±8.00
Juveniles	23	23	23.00±0.00
Subadult females	7	5	6.00±1.00
Subadult males	15	9	12.00±3.00
Subadults unknown	3	2	2.50±0.50
Juveniles: Adults	1.00:12.26	1.00:11.00	1.00:11.63

Sub-adults: Adults	**1.00:11.28**	**1.00:10.12**	**1.00:10.70**
Male: Female	**1.00:1.87**	**1.00:1.83**	**1.00:1.86**

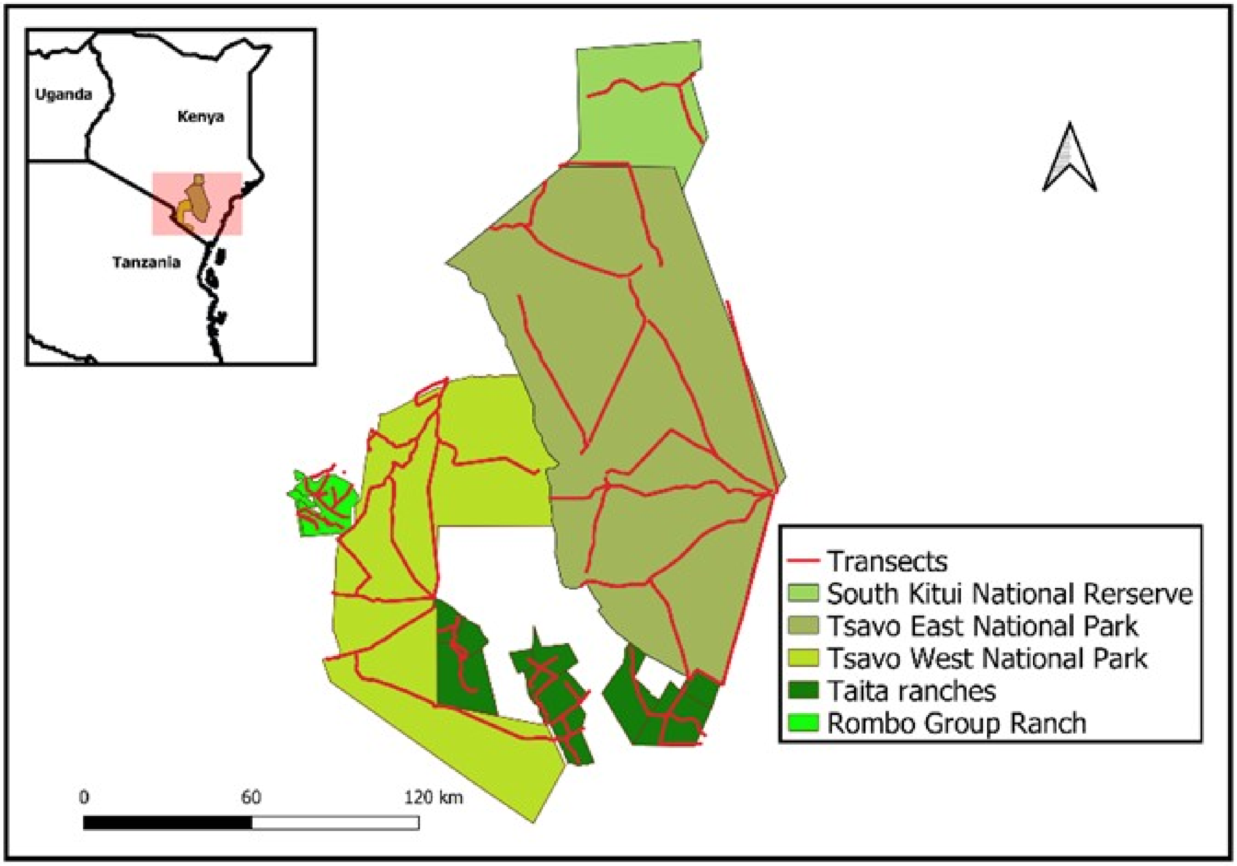
FIGURE LEGENDS

Figure 1. Panel a depicts the location of the study area showing the Tsavo landscape including four study sites in Tsavo West National Park, South Kitui National Reserve, Tsavo East National Park, Rombo Group Ranch, and the Taita ranches and Masai giraffe (*Giraffa camelopardalis tippelskirchi*) distribution in the Tsavo landscape. It also shows the distribution of the 51 road transects used during the Masai giraffe (*Giraffa camelopardalis tippelskirchi*) study. Panel b shows giraffe sightings in the dry season and panel c shows giraffe sightings in the wet season.

FIGURES

Figure 1.

a.)



b.)

c.)