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Density Estimate and Habitat Association of Cape Buffalo (*Syncerus caffer caffer*) in Forested Ecosystem of Western Ethiopia

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ABSTRACT

A study on density estimate and habitat association of Cape buffalo (*Syncerus caffer caffer*) in Jorgo-Wato Protected Forest, Ethiopia, was carried out from 2016-2017 encompassing the wet and dry seasons. The density of Cape buffalo was estimated indirectly through faecal standing crop and faecal accumulation rate dung count methods. Dung piles were counted using strip transects laid in proportion to the predetermined Cape buffalo density in six blocks. Habitat association was inferred from direct and indirect evidences assuming that Cape buffalo signs were proportional to their distribution and habitat use. The density of Cape buffalo was 0.77 individuals/km^2 in wet and 0.64 individuals/km^2 in dry seasons. Cape buffalo utilized more open (23.1%) and plantation (19.3%) forests during the wet season and open (18.5%) and riparian (13.2%) forests during the dry season. Dense forest was less utilized during both seasons but riparian forest during the wet season. Density of Cape buffalo was low in Jorgo-Wato Protected Forest which could be linked to the impacts of various anthropogenic activities in the forest. Intense human pressure during the daytime made Cape buffalo rest in thicket riverine forest during the day but in open forest, on road and clearings during the night time.

Key Words: Cape Buffalo, Dung Count, Density Estimate, Ethiopia, Jorgo-Wato Protected Forest

INTRODUCTION

African buffalo are the biggest ungulates (Smithers 1983) and most formidable bovid in Africa (Estes 1991). They belong to the Family Bovidae and vary in size and colour depending on the subspecies (Skinner and Smithers 1990). African buffalo are the only representative of the genus *Syncerus* in Africa and the largest African mammal with great morphological variations (du Toit 2005). As revealed by East (1999), four valid subspecies are recognized. These include: forest buffalo (*Syncerus caffer nanus*), West African savanna buffalo (*Syncerus caffer brachyceros*), Central African savanna buffalo (*Syncerus caffer aequinoctialis*) and Cape buffalo (*Syncerus caffer caffer*). The mountain buffalo, *Syncerus caffer mathewsi* may also be a valid subspecies identified in Eastern Africa (IUCN SSC Antelope Specialist Group 2008). As described by Skinner and Smithers (1990), considerable intergradations are observed between the savanna subspecies and forest buffalo in areas where their ranges overlap. *Syncerus c. aequinoctialis* and *S. c. brachyceros* are an intermediate subspecies between *S. c. caffer* and *S. c. nanus* (du Toit 2005).

The ecology of African buffalo has been the focus area for a number of comprehensive scientific studies (Sinclair 1977, Prins 1996) as they are playing significant role both in the ecology and economy of many countries (Lindsey Roulet and Romañach 2007). They are ecologically important for their role as a bulk feeder, facilitate feeding for lower grazers and nutrient cycling. They are the most preferred prey by lion in many savanna ecosystems (Sinclair 1977, Prins 1996, Jolles et al. 2005, Munagandu et al. 2006). Apart from their ecological significance, they are important in attracting tourists (Michel and Bengis 2012), subsistence hunting and photographic safaris (Sinclair 1977). Economically, African buffalo play a great role in trophy hunting (Sinclair 1977). They have attracted the attention of most hunters in East and Southern African countries (Vander et al. 2004). Currently, they are the key animals sought for trophy hunting industry since other game animals are declining and threatened to extinction (Munagandu et al. 2006). Hence, it is a species of conservation concern in many East and Southern African countries. Unfortunately, Ethiopia has not yet used the species effectively for income generation (Lindsey et al. 2007).

African buffalo have been widely distributed throughout sub-Saharan Africa (Sinclair 1977, Skinner and Smithers 1990). They survived in most protected areas of Africa ranging from the east to the west and from central to southern Africa (Sinclair 1977). Once ranging widely in sub-Saharan Africa, their distribution has shrunk due to poaching and habitat loss (East 1999, IUCN SSC Antelope Specialist Group 2008). Of all subspecies, *S. c. caffer* is abundant and widely distributed in Africa. Currently, they occur in many protected areas of the Southern and East African countries (East 1999). African buffalo is one of the most successful large African mammals in terms of geographic range, abundance and biomass (Estes 1991). However, due to severe habitat fragmentations, significant numbers of African buffalo are limited to occur in fewer protected and unprotected areas (Winterbach 1998).

Population estimate of savanna buffalo and forest buffalo was about 830, 000 and 60, 000, respectively, during the end of the 19th century (East 1999). More than three-quarters of them were found in protected areas. African buffalo are categorized as a species of least concern as per the evaluation criteria of the IUCN, but their current population trend are decreasing (IUCN SSC Antelope Specialist Group 2008). This is caused by high human population, which exacerbates habitat loss, poaching and drought (Skinner and Chimimba 2005). Several studies have shown that bovine tuberculosis (Jolles et al. 2005), rinderpest (Winterbach 1998), anthrax (De Vos and Bryden 1996), foot and mouth diseases (Vosloo et al. 2002) have threatened buffalo species.

In Ethiopia, only few secondary sources revealed the former and current ranges of African buffalo. For example, African buffalo have been known to exist in central and eastern Ethiopia, particularly in the Awash and the Webi Shabelle river valleys before 1890s (East 1999) and in the Nechisar National Park, but all are eliminated (Gidey et al. 2014). African buffalo are currently limited to the well-watered parts of the western and southwestern lowlands of Ethiopia (East 1999). Previous studies have also confirmed that buffalo exist in Omo and Mago (Lamprey 1994), Chebera Churchura (Abraham Megaze 2015), Gambella (EWCA 2010), Alatish (Girma Mengesha and Afework Bekele 2008) and Dhati Wolel (Gutema Jira 2015) National Parks. Furthermore, they are also known to exist in most protected areas and remnant forest patches of their former ranges in the west and southwestern parts of Ethiopia. In spite of the diverse economic and ecological significances of African buffalo, their population size, distribution and habitat association are poorly known in Ethiopia. So far, the population of African buffalo was estimated to be 5193 individuals in the Chebera Churchura National Park (Aberham Megaze 2015), 2974 individuals in Dhati Wolel National Park (Gutema Jira 2015) and 700 individuals in the Omo National Park and the surrounding buffer zone (Renaud 2007). Studying the population size and distributions of species have great conservation value (Ramachandran et al. 1986, Varman and Sukumar 1995) and a tool for game and wildlife management (Borkowski et al. 2011). Historically, Cape buffalo was not known as inhabitants of Jorgo-Wato Protected Forest and dense forested habitats shifting from savanna woodland and grassland habitats. They shifted into Jorgo-Wato Protected Forest from the lowland savanna woodland habitats due to human induced pressure. Thus, the aim of this study was to estimate the density and habitat association of Cape buffalo, which would be useful to design future conservation and management strategies of Cape buffalo populations in a newly colonized range.

STUDY AREA

Jorgo-Wato Protected Forest (JWPF) is located in the Oromia Regional State of Ethiopia between West Wollega and Buno Bedele Administrative Zones. It is approximately 509 km west of Addis Ababa. The forest is particularly located between Nole Kabba (West Wollega) and Meko (Buno Bedele) districts. JWPF is situated between 8°40’ 20’’ to 8° 48’ 06’’N latitude and

35º 48' 01'' to 35º 56' 40''E longitude. It was proposed as one of the top National Forest Priority Areas in 1976 and demarcated in 1988 with an estimated area of 19,875 ha. People surrounding the forest have been relocated during the Derg regime, with the objective of scaling up the forest through the afforestation of the glades and the surrounding steep slope areas that are not convenient for farming. However, relocated people back to their former lands following the fall of the Derg regime in 1991, and started planting coffee in the afforested area. Consequently, the forest was re-demarcated in 2013 excluding the forest parts owned by the former residents. The later demarcation has reduced the total area of JWPF to 8,503.49 ha. JWPF is locally administered by the west Wollega Forest and Wildlife Enterprise, under Oromia Forest and Wildlife Enterprise. The area of the forest is reducing due to severe human pressure for coffee plantation, shifting cultivation, selective logging and livestock grazing. The study area receives a unimodal annual rainfall. The wet season covers from April to October, whereas the dry season comprises from November to March. The mean annual rainfall from 1992 to 2014 was 1805 mm. The mean monthly maximum temperature was 28ºC recorded in February and March, but the mean minimum was12ºC recorded in July and August.

The highland areas of the southwestern part of the country are categorized as moist evergreen Afromontane forest, which comprises broad leaved evergreen species (Friis et al. 2011). The moist evergreen montane forests of the south and southwest parts of Ethiopia are good sources of gene pools for several domesticated wild plants (NBSAP 2005). Similarly, JWPF is a good reservoir of *Coffee arabica*, *Aframomum corrorima* and *Rhamnus prinoides,* which are used as sources of income by the local communities. JWPF comprises exotic species such as *Eucalyptus* spp. *Cupressus lusitanica*, *Grevillea robusta* and *Pinus patula*. The natural vegetation of the study area was relatively homogenous in terms of species composition.

The study area was classified into four habitat types following vegetation inventory and description methods of White and Edwards (2000). These habitat types include: Dense primary forest (dense forest), open secondary forest, (open forest), riverine and riparian forest and plantation forest. Dense forest mainly composed of primary forests with long trees forming closed upper canopy. This habitat has shade tolerant shrubs such as *Dracaena afromontana* and *Hypoestes forskaolii* and grass species such as such as *Setaria poiretiana* and *Panicum hochstetteri*. However, in matured parts of the forest, the ground lacks understory

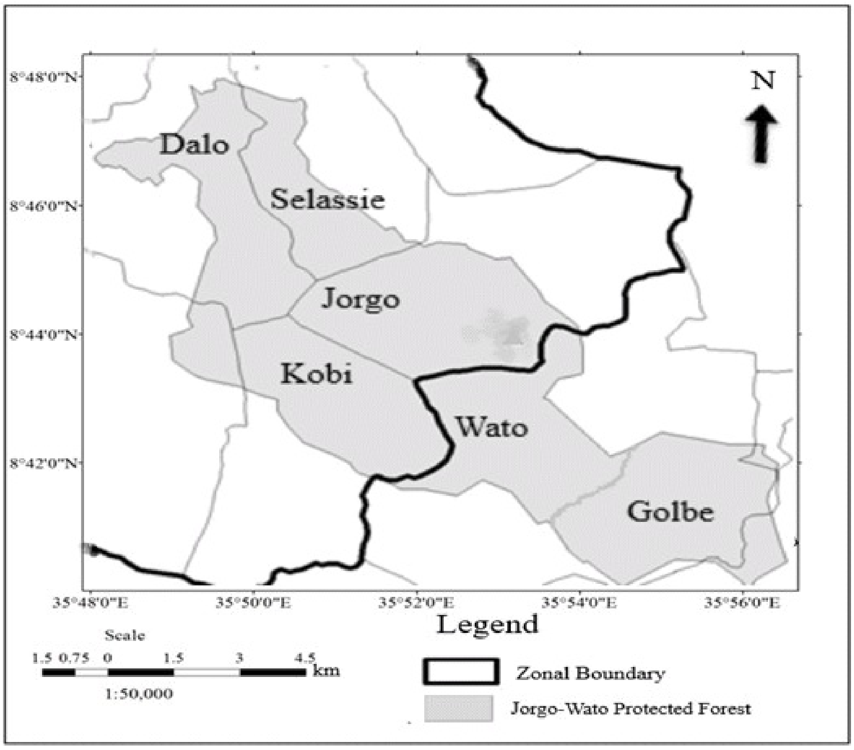

Figure 1. Map of JWPF indicating the six blocks where dung piles were counted

covers. Open forest habitat is characterized by large mature trees and clear evidences of past human utilization and residences. The forest is open from the ground with irregular distributions of shrubs and bushes. The understory covers include *P. hochstetteri* during both seasons but *C. distans* during the wet season. Riverine and riparian forests comprise thick forests with interwoven lianas. The riparian bank was open and comprises *P. hochstetteri, C. distans, S. poiretiana* and *C. fischerianus.* Plantation forest consists of *Eucalyptus* species*, C. lusitanica, G. robusta* and *P. patula* species. It also contains understory grass covers such as *S. poiretiana, C. distans, Cynodon dactylon* and annual herbs such as *Bidens ghedoensis, Biden spilosa, Galinsoga quadriradiata, Guizotia scabra* and *Satureja paradoxa* which grow more in glades during the wet season, but deteriorate during the dry season.

METHODS

Density of Cape buffalo was determined indirectly through dung counts because it is impossible to apply direct method in thicket forest. Faecal standing crop (FSC) and faecal accumulation rate (FAR) methods were employed for dung counts. Both dung count methods were conducted once each during wet and dry seasons. Faecal standing crop involves the counting of all dung observed within the sampling areas, whereas FAR (clearance count) involves counting dung from areas that were initially cleared of all dung (Mayle et al. 1999, Marques et al. 2001, Laing et al. 2003, Mandujano 2014). The study area was classified into nine blocks (Norton-Griffiths 1978) out of which six blocks were selected based on frequent observations of dung piles, footmarks, information from forest wardens and local people about areas where Cape buffalo frequented (Figure 1). The six blocks were further classed into high (Jorgo and Dalo), medium (Selassie and Wato) and low (Kobi and Golbe) buffalo density areas as described by Marques et al. (20001). This would help to allocate comparable sampling efforts to increase the accuracy of density estimates (Norton-Griffiths 1978, Plumptre 2000, Marques et al. 2001). Study blocks were delineated by local ward boundary such as mountains, steep slopes, valleys, road and rivers (Norton-Griffiths 1978). In each block, strip transects of 10 m width and 0.5 to 1.5 km length was laid (Plumptre and Harris 1995, Bekhuis et al 2008). This was used to increase the probability of detecting dung in dense understory covers and efficiency where a species of concern had low density (Camargo-Sanabria and Mandujano 2011). Strip transects were laid in proportion to the predetermined Cape buffalo density in each study block. A total of 49 strip transects were laid perpendicular to rivers and gravel road, but not set on mountains, escarpments, gorges and impenetrable areas (Norton-Griffiths 1978). Transects were spaced at intervals of 1 km, 1.5 km and 2 km based on accessibility, landscape and predetermined status of Cape buffalo density in the area. Faecal standing crop count was carried out in the forested part during the wet (May, 2017) and dry (February, 2017) seasons. Transects were walked with one militia and one forest warden during the entire dung counting periods. As stated by Jachmann (2001), calves produce droppings very slowly, which is less accessible and decay faster than the fibrous and large droppings of adults. Hence, 5% of dung counted was added to compensate error due to fast decay and inaccessibility of calf's dung.

Faecal accumulation rate was conducted in clearings to estimate Cape buffalo density (Plumptre and Harris 1995, Marques et al. 2001, Bekhuis et al. 2008). Two strip transects of 0.5 km length and 10 m width were laid each in the three cleared areas. During the first visit, dung was totally removed from laid transects during the wet (October, 2016) and dry (December, 2016) seasons. Then, all new Cape buffalo droppings were counted after 21 days of the first visit assuming that new dung piles did not disappear within the time interval of dung clearing and counting. Hence, dung disappearance time was not considered in FAR method of density estimation (Marques et al. 2001, Laing et al. 2003). However, the same defecation rate was used to estimate Cape buffalo density in both FSC and FAR methods. For this study, the mean defecation rate of African buffalo reported by Plumptre and Harris (1995) that is 5.1 dung per day per individual was used. However, the mean number of days in which Cape buffalo dung decayed in the area was 42 days (Erena et al. 2019).

Distribution and habitat association of Cape buffalo were inferred from both direct and indirect evidences that show buffalo occurrence assuming that the recorded signs were proportional to their distribution and habitat use (Macleod et al. 1996, Shrestha et al. 2005). Footmarks, forage signs, dung piles, buffalo trails, direct sight, carcasses and scratched tree barks attributed to buffalo were used as indicators of distribution and habitat use (Mwambola et al. 2016). All indirect evidences were recorded if they were assumed to be independent of the previous records in different habitats.

Density of Cape buffalo (D_b), was estimated using the formula outlined by Mayle et al. (1999) as:

$$D_b = \frac{D_s}{p \times t}$$

Where: D_s is the dung pile density, p is defecation rates per day and t is the mean dung decay time in days. Dung counted from clearings was also used to calculate Cape buffalo populations as described by Mayle et al. (1999). Number of Cape buffalo per km^2

The area surveyed using strip transect line was calculated as $a = 2wL$, where $2w$ is the width whereas L is the total length of a transect. The overall population size of Cape buffalo was estimated from FSC and FAR methods by multiplying the mean Cape buffalo density with the total area (Wilson et al. 1996, Mulama 1997). Dung pile density recorded during the wet and dry seasons was tested by one-way analysis of variance (ANOVA). Dependent-sample t-test was used to compare overall sighting of Cape buffalo signs between the wet and dry seasons, but non-parametric Kruskall-Wallis test was used to test differences in the frequency of indicators of Cape buffalo occurrence among the study blocks. Distribution and habitat association, dung density and population estimate of Cape buffalo during the wet and dry seasons were tested by Chi-square test.

RESULTS

Density Estimate

A total of 123 dung piles were recorded from 49 transects of 39 km length walked in six blocks encompassing the wet and dry seasons. The number of dung piles recorded in different blocks differed significantly between the wet (n = 71) and dry (n = 52) seasons (t = 3.17, df = 5, $p < 0.05$). The highest dung pile density was recorded in Dalo (229 km^{-2}), followed by Jorgo (196 km^{-2}) and Selassie (184 km^{-2}). The least was recorded in Kobi (66 km^{-2}) and Golbe (32 km^{-2}). In FSC method, 144 km^{-2} (95% CI: 114–176) mean dung pile density was recorded in JWPF (Table 1).

Dung pile density recorded during the wet and dry seasons differed significantly across different blocks ($F_{5, 6} = 5.64$, $p < 0.05$). Among the six surveyed blocks, the highest Cape buffalo density was recorded in Dalo (1.06 km^{-2}), followed by Jorgo (0.91 km^{-2}) and Selassie (0.85 km^{-2}), whereas the least was recorded in Golbe (0.15 km^{-2}). The total estimated Cape buffalo density in the area was 0.67 km^{-2} (95% CI: 0.53–0.81). Dung density in different blocks differed significantly between wet and dry seasons ($\chi2$ = 194.84, df = 5, $p < 0.05$). The mean Cape buffalo density estimated by FSC method was 0.67/km^2 (Table 2).

In FAR, only five dung piles (Wet = 3; Dry = 2) were recorded in clearings (Table 3). Though the number of dung piles was only few, it resulted in a high number of buffalo density during the wet (0.82 km^{-2}) and dry (0.65 km^{-2}) seasons. The estimated number of Cape buffalo during the wet (66.0) and the dry (54.0) seasons were determined from seasonal mean buffalo density of the FSC and FAR methods. There was no significant difference in the number of estimated Cape buffalo during the two seasons ($\chi2$ = 0.28, df = 1, $p > 0.05$). With a mean Cape buffalo density of 0.71 km^{-2} obtained from both faecal count methods, the total number of estimated Cape buffalo in the study area was 60 (52 to 68).

Table 1. Density estimate of Cape buffalo in JWPF (Mean number of days in which the dung decays (42.25 days) was used for density estimation; *indicates mean value).

Blocks	Total transects	Sampled area (km^2)	No. of dung piles counted	5% of dung piles counted	Dung pile density km^{-2}	Estimated buffalo km^{-2}
Dalo	12	0.22	48	2.40	229	1.06
Jorgo	12	0.22	41	2.05	196	0.91
Selassie	8	0.08	14	0.70	184	0.85
Wato	8	0.08	12	0.60	158	0.73
Kobi	4	0.08	5	0.25	66	0.31
Golbe	5	0.10	3	0.15	32	0.15
Total	49	0.78	123	6.15	144*	0.67*

Table 2. Pooled seasonal density estimates of Cape buffalo in JWPF as determined by FSC method.

Season	Dung density km^{-2}		No. of buffalo/km^2	
	Mean±SE	95% CI	Mean±SE	95% CI
Wet	154.83±25.44	106.01–203.65	0.72±0.23	0.48–0.96
Dry	133.50±11.63	112.17–154.83	0.62±0.11	0.52–0.72
Mean±SE	144.17±16.81	113.84–174.50	0.67±0.15	0.53–0.81

Table 3 Seasonal density estimates of Cape buffalo in JWPF using FAR method (*=indicates mean value).

Survey site	Season	Sampled area (km^2)	Number of dung piles	5% of dung piles counted	Dung density	Estimated buffalo km^{-2}
Clearings	Wet	0.03	3	0.15	105.0	0.82
	Dry	0.03	2	0.10	70.0	0.65
	Total	0.06	5	0.25	87.5*	0.74*

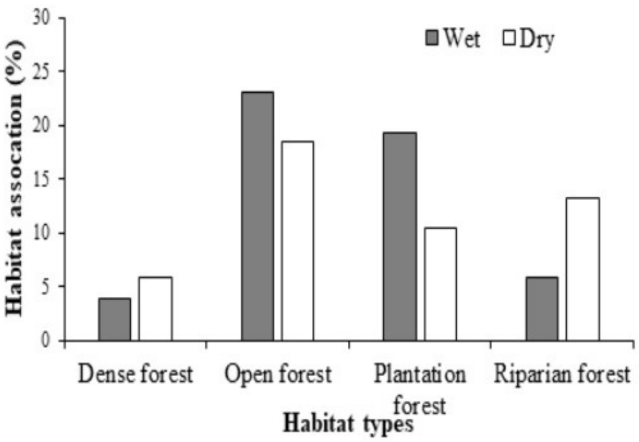

Figure 2. Habitat association (%) of Cape buffalo during the wet and dry seasons in JWPF

Habitat Association

A total of 363 independent signs attributed to Cape buffalo was recorded during the wet (*N* = 219) and dry (*N* = 144) seasons to describe their distribution and habitat association. The frequencies of encountered signs were high for footmarks and foraging signs (*N* = 141, 38.84%), followed by dung piles (*N* = 123, 33.88%) and scratched tree barks (*N* = 59, 16.26%). The lowest encounter was recorded for carcasses (*N* = 2, 0.55%). Different signs attributed to the occurrences of Cape buffalo differed significantly between seasons ($t = 2.92$, df = 5, $p < 0.05$). The distribution of Cape buffalo signs recorded in different blocks include Jorgo (*N* = 111, 30.6%), Dalo (*N* = 93, 25.6%), Selassie (*N* = 72, 19.8%), Wato (*N* = 57, 15.7%), Kobi (*N* = 24, 6.6%) and Golbe (*N* = 6, 1.7%). The frequency of indicators of Cape buffalo occurrence in different study blocks showed significant difference (Kruskal-Wallis H test, $p < 0.05$).

Distribution and habitat association of the Cape buffalo were inferred from the number of signs attributed to Cape buffalo recorded in different habitats and seasons. Accordingly, Cape buffalo frequently utilized open forest (23.1%) and plantation forests (19.3%) during the wet season and open forests (18.5%) and riparian forest (13.2%) during the dry season. During both seasons, dense forest was less frequently utilized by Cape buffalo and riparian forest (5.9%) during the wet season (Figure 2). The distribution of signs attributed to Cape buffalo in different habitat types during wet and dry seasons showed significant variation ($\chi2 = 22.78$, df = 3, $p < 0.05$).

DISCUSSION

Population estimates of elusive mammals in the forested habitat are hardly determined through direct method, mainly due to poor visibility and vigilance behaviour of animals (Norton-Griffiths 1978, Karanth and Sunquist 1992, Varman and Sukumar, 1995, Marques et al. 2001, Blake 2002b). Similarly, ecological study of Cape buffalo through direct method was impractical in JWPF due to the following main reasons. First, it was too difficult to see Cape buffalo in the thicket forest. Second, anthropogenic factors such as poaching and other illegal resource extractions have increased the vigilance behaviour of Cape buffalo, and altered their activity almost into nocturnal and crepuscular. Third, the population size of Cape buffalo was assumed to be low and made their observation infrequent. Within this circumstance, the application of indirect method was more realistic and recommended than direct method (Norton-Griffiths 1978, Bailey and Putman 1981, Putman 1984, Merz 1986, Plumptre and Harris 1995, Marques et al. 2001, Laing et al. 2003). Hence, the population estimate of Cape buffalo was determined indirectly through dung counting techniques in JWPF.

Dung count techniques have been developed to estimate the population of elephants and other forest inhabited mammals (Barnes and Jensen 1987, Plumptre and Harris 1995). However, this was rarely employed for savanna buffalo because savanna and savanna woodland habitats are often appropriate for direct methods. Liang et al. (2003) stated that the difficulty of direct method in population estimates of mammals in the forest has led to the application of indirect survey methods. Hence, dung decay rates and related concepts in the present study were compared more with elephants as the dung decay study has been scarce for African buffalo. Estimates of animal population from dung require dung production rate and disappearance or decay time to convert it into estimates of animal abundance (Barnes and Jensen 1987, Liang et al. 2003).

High Cape buffalo density was recorded in Dalo, Jorgo and Selassie blocks as determined during preliminary survey and information from different sources. This could be attributed to the following reasons. First, Dardara is a large mineral water source located outside of JWPF, approximately at 5 km north of Dalo and Selassie forest edges. Hence, Cape buffalo take refugia in Dalo and Selassie forest blocks to often visit Dardara mineral water at night. As described by Bailey et al. (2001), attractants such as salty supplements modify the distribution and grazing patterns of herbivores, as they frequently travel to attractants and graze in nearby areas. Second, Dalo and Selassie forest blocks, along with Dardara mineral water have been considered as the hypothesized route through which Cape buffalo first invade JWPF. Hence, they have been well adapted to these areas and less likely moved away to the southern portions of JWPF. Moreover, Dalo and Selassie forest blocks relatively possess an open secondary forest with good grass cover and rivers compared to the central and southern portions of JWPF. This agrees with the findings of Bailey et al. (1996), who described that large herbivores spend most of their time in areas of high quantity and quality forages. Large herbivores precisely adapt a spatial location of essential resources and frequently utilize such areas (Bailey and Provenza 2008). Moreover, Cape buffalo prefer riverine areas as it provides sufficient food, shade and wallow area especially during the dry season (Sinclair 1977). Third, Jorgo block is located at the centre of JWPF, south of Dalo and Selassie mostly serving as main route for Cape buffalo towards Wato, Kobi and Golbe forest blocks. Moreover, it was probably one of the most important secured areas for Cape buffalo due to many valleys, montane forests and inaccessible terrains that provides safer refugia during both seasons.

During the dry season, high Cape buffalo density was recorded in Wato forest block. This could be attributed to a minor habitat shift of Cape buffalo towards Wato forest block due to increased human resource extraction around Jorgo, Dalo and Selassie forest blocks. *Rhamnus prinoides, C. arabica* and *A. corrorima* were the most important wild resources extensively extracted from the three blocks during the dry season. Mostly, large herbivores are limited from areas of high human and livestock disturbances. Danquah and Oppong (2014) have also shown that large mammals, including African buffalo avoid human-dominated habitats for security reasons. Moreover, seasonal variation in resource availability and other environmental conditions help animals to determine when each habitat types to be used (Borger et al. 2006). Large herbivores use seasonal habitat shift to adjust to resource variability to realize their basic nutritional requirements (Delany and Happold 1979, Bailey et al. 1996).

The mean density estimate of Cape buffalo (0.71 km^{-2}) in JWPF was comparable to values estimated for West African savanna buffalo in Arli National Park (0.82 km^{-2}), Burkina Faso (Bouché et al. 2004), but higher than the values estimated for forest buffalo in the Campo-Ma'an National Park (0.01 km^{-2}), Cameroon (Bekhuis et al. 2008), Cape buffalo in Meru Conservation Area (0.19 km^{-2}), Kenya (Mwangi et al. 2007) and Tswalu Reserve (0.15/km^2), South Africa (Cromhout 2006). However, it was lower than the values reported elsewhere in Lake Manyara National Park (17.9/ km^2) and Serengeti National Park, Tanzania (6.8 km^{-2}) (Prins 1996), Dhati Wolel National Park, Ethiopia (6.17 km^{-2}) (Gutema Jira 2015) and Chebera Churchura National Park (4.27 km^{-2}), Ethiopia (Aberham Megaze 2015). The density of African buffalo varies from place to place based on availability of diet, which eventually depends on rainfall (Sinclair 1977, East 1984, Prins 1996). However, the reason for the low density of Cape buffalo in JWPF could be attributed to the small area cover of the forest, anthropogenic disturbances and poaching, which altogether put Cape buffalo in great trauma. Moreover, the number of Cape buffalo first colonized JWPF might have been very low and male biased.

The estimated number of Cape buffalo during the wet season was higher than the dry season, agreeing with the finding of Aberham Megaze (2015). The insignificantly higher number of estimated Cape buffalo populations during the wet season could be attributed to the high defecation rate, and open habitat utilization of Cape buffalo, which makes dung piles more accessible during counting. Studies have shown that daily defecation rate varies seasonally and are influenced by habitat quality and availability of forages (Dzieciolowski 1976, Mitchell et al. 1985, Mayle et al. 1996). However, during the dry season, as human activities increase in the forest, Cape buffalo were limited to inaccessible areas, which could be the cause of the reduction of dung piles along the accessible areas. Similarly, high numbers of forest buffalo were recorded around water courses and forest clearings in the primary forest of northern Republic of Congo (Blake 2002a). Cape buffalo preferred open forest habitats, clearings and gravel roads during the night time and limit themselves to dense and thicket riparian vegetation during the daytime in JWPF.

All habitat types do not possess balanced resources, and have not equally used by ungulates throughout the year (Bjørneraas et al. 2011). Consequently, habitat utilization by ungulates varies on seasonal and circadian basis (Demarchi and Bunnell 1995, Dussault et al. 2004) and governed by trade-offs between associated costs and benefits (Rettie and Messier 2000). To optimise costs and benefits, ungulates use different habitats at different periods. In JWPF, Cape buffalo avoids open forest habitats during the daytime, but utilize it at night as described by Hebblewhite et al. (2008) and Godvik et al. (2009). As reported by Melletti et al. (2007), forest buffalo was highly dependent on open forest habitats and clearings in Bai-Hokou forests of Dzanga-Ndoki National Park, Central African Republic. In JWPF, Cape buffalo preferred plantation and open forests during the wet season due to the availability of adequate forages and limited human access. In open savanna habitats, African buffalo experiences high heat stress and restrict themselves from daylight foraging (Prins 1996). In JWPF, Cape buffalo has not faced the problem due to the closed shade of the forest. However, they have shifted their foraging activity into nocturnal and crepuscular due to high human disturbances during the daytime. Di Bitetti et al. (2008) stated that increased poaching pressure could alter activity patterns of the hunted species into nocturnal. As reported by Skinner and Smithers (1990), African buffalo mostly graze closer to rivers and take shelter in the thick riverine vegetation, for temperature regulation, in open savanna habitats. Hence, the difference in habitat association of Cape buffalo in JWPF might not be a function of temperature regulation during the dry season, but a response to human pressure. An increased association of Cape buffalo to riparian habitats could be linked to risk avoidance in the open forest. To optimise cost-benefit relationships, ungulates may use habitats with good cover during the daytime (Demarchi and Bunnell 1995, Dussault et al. 2004) and visit open forage-rich habitats during the night (Godvik et al. 2009, Lykkja et al. 2009). In JWPF, Cape buffalo did not prefer dense forest at night time due to limited forage as reported by Perrin and Brereton-Stiles (1999). This study revealed that the behavioral ecology of Cape buffalo in general and their habitat association in particular are flexible in response to various ecological and anthropogenic factors. This helps to uncover the critical areas of the ecology of other large mammals that have shifted their range due to various environmental and human induced pressure.

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