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Population Size vs. Age structure and Seasonal movement pattern of African Elephants (*Loxodonta africana*, Blumenbach, 1797:Elephantidae) in Babile Elephant Sanctuary, Eastern Ethiopia

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ABSTRACT

The focus of this paper is to study the population size and age structure of elephants, and their seasonal movement patterns in Babile Elephant Sanctuary (BES), Eastern Ethiopia. The study was carried out between May 2019 and April 2020. The population size of the elephant was estimated indirectly from the dung droppings using line-transect methods within a 42 km2 area; of which, each 12 km2 area in riverine and woodland, and 18 km2 in bushland habitats. The total estimate of the elephant population for the sanctuary was (230±20) or between (210 and 250). Besides, Elephant numbers were also estimated directly from sightings. The maximum number observed in a herd was 75. There was a declining trend for the past 49 years in the elephant population. The observed density for the whole sanctuary was 0.033 elephants per km2. In the elephant age structure, there were more intermediate (47%) and very few sub-adults (2.6%) size classes identified. The movement pattern of elephants was studied based on footprints, dung piles, and feeding signs The GPS recorded routes were marked on a geo-referenced map of the area using a GIS program (Arc map10.8). The result revealed that the present wet and dry seasonal movement patterns of elephants were noted following almost the Erer and Gobele valley routes in the oromia region of the sanctuary. Based on the study results, the following inference is drawn: identifying and documenting up-to-date information on population size and age structure, and seasonal movement of African elephants (i.e., the migratory routes and foraging areas for complete protection to maintain the animal's natural migratory patterns without disturbance) in BES is important to build gaps in knowledge for conservationists to design plans for restoring the species and sustaining the elephant's existence. Therefore, strengthening the capacity of management and enforcing laws can minimize intimidation and enhance opportunities.

Keywords: African elephants, Age structure, Dung dropping, Movement pattern, Population size, Transect line.

1. INTRODUCTION

Elephants are among the larger mammals of Ethiopia that required a wide distribution (Largen and Yalden, 1987). In Ethiopia, among the three subspecies of the African elephants (i.e., *Loxodonta africana oxyotis, L. a. Knochenhalleri, and L. a. orleansi*); *L. a. orleansi* has occurred only in the Babile Elephant Sanctuary (BES) (Largen and Yalden, 1987). During the beginning of the sanctuary establishment (in 1970), there was 600 elephant population were occurred (Stephenson, 1976), due to occurrences of different anthropogenic impacts inside the sanctuary (e.g., killing of elephants mainly through poaching to satisfy the demand for ivory and habitat encroachment through various activities like settlement, HEC for the use of land, deforestation for fuelwood and charcoal), the population number was influenced (Anteneh Belayneh ,2006; Yirmed Demeke *et al*., 2006; Zelalem Wodu, 2007; Sintayehu *et al*., 2016), Hence, the total elephant population was declined. For instance, 300 elephant populations were recorded in 1986 (Yalden *et al*., 1986); 264 in 2006 (Yirmed *et al*., 2006); and 237 in 2015 (Sintayehu *et al*., 2016), which was alarmingly decreasing by 50% when relating with the establishment period. At present reliable estimates of elephant population numbers and

Age-structure in the sanctuary has not been known. Elephants in BES have a movement pattern following the four main drainage river valleys in the sanctuary (Fafem, Daketa, Erer, and Gobele) in the past (Anteneh Belayneh, 2006, Yirmed Demeke *et al*., 2006). However, presently they follow only the Erer and Gobele Valley which is located mostly in the Oromia regional state. The present wet and dry seasonal distributions of elephants were following the same routes except the direction was back and forth or in the opposite direction. So, this study aims at collecting data using different types of observations to get an up-to-date and relatively more accurate estimate of elephant numbers using the line transect technique and also identify the present elephant routes (i.e., their specific local areas), and allocate specific area-based conservation monitoring activities, Therefore, knowing elephant population, age structure, and seasonal movement patterns are important, for the contribution in developing the sanctuary management plan and conservation policy (Yirmed Demeke *et al*., 2006; EWCO, 1991; Hillman, 1993).

2. MATERIALS AND METHODS

2.1. Location of Study Area

Babile Elephant Sanctuary (BES) was established in 1970, with an area coverage of about 6,982 km^2. It is located at about 560 km distant from the capital city of Addis Ababa in the eastern part of the country; between Oromia and Ethio-Somali regional states. Its geographical position is within latitudes of 08^{o}22'30"-09^{o}00'30"N and longitudes of 42^{o}01'10"- 43^{o}05’50"E (Figure 1). It is a part of the Somali-Masai Centre of Endemism and is located between the Eastern Hararge high mountain (i.e., Mountain Gara-Muleta to the west) and the Ogaden Desert to the southeast (Yirmed Demeke cited in Emily and Elizabeth, 2021).

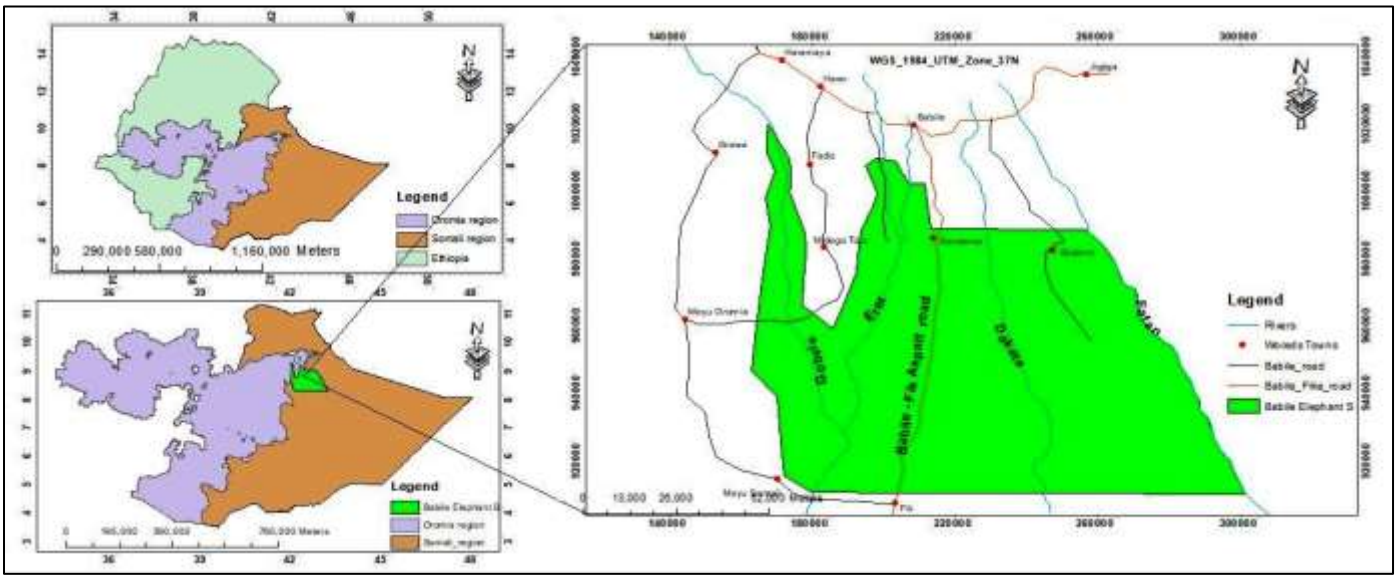

Figure 1. Location Map of Babile Elephant Sanctuary

2.2. Study Area Description

The topography of the land has altitudinal ranges of 850 to 1,785 meters above sea level (m.a.s.l.) and about (84%) of the total sanctuary area is mainly described as flat to gentle slopes, while the remaining (16%) are composed of complex valleys and deep gorges (Yirmed Demeke, 2008). The sanctuary has a tropical rainfall climate (Woinadega) and a tropical arid climate (Kola) type. It has the mean annual temperature (maximum 28.53 ^{o}C and minimum 12.42 ^{o}C) and has the mean monthly temperatures (maximum 32.39 ^{o}C and minimum 9.66 ^{o}C) recorded respectively (Source: National Metrological Service Agency (NMSA) data from 2002 to 2016) (Figure 2). Slight temperature differences were observed throughout the year (Figure 2). The hottest months were recorded between April and June while the coldest months were recorded between October to January (Source: NMSA data from 2002 to 2016) (Figure 2). In general, the highest (32.39 ^{o}C) and lower (9.66 ^{o}C) mean monthly temperature was recorded in April and January respectively (Figure 2). In the sanctuary, there are two rainy seasons (i.e., bimodal rainfall). The short and long rainy seasons' were recorded from March to May and June to October respectively. Even in the other seasons, a small amount of rainfall was yearly distributed (Nov- 79.9 mm, Dec- 42.3 mm, Jan-5.15 mm, and Feb-44.3 mm) (Source: NMSA data from 2002 to 2016) (Figure 2). There were high variations of rainfall ranging from year to year, ranging from 442 mm to 1302.9 mm/yr with a mean annual rainfall of 802 mm. In the short rainy seasons, the mean monthly rainfall from March to May (Mar-96.5 mm, Apr-117.05 mm, May-131.7 mm) and the long rainy seasons, from June to October (Jun-93.6 mm, July-54.5 mm, Aug-87.5 mm, Sept-59.55 mm, and Oct- 80.7 mm) were recorded (Figure 2). The mean monthly rainfall was 66.8 mm, and the mean maximum (127.7 mm) and mean minimum (5.21 mm) monthly rainfall was recorded (Source: NMSA data from 2002 to 2016) (Figure 2). In

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general, the highest mean monthly rainfall (131.7 mm) in May and the lowest mean monthly rainfall (5.13 mm) in January were recorded (Figure 2).

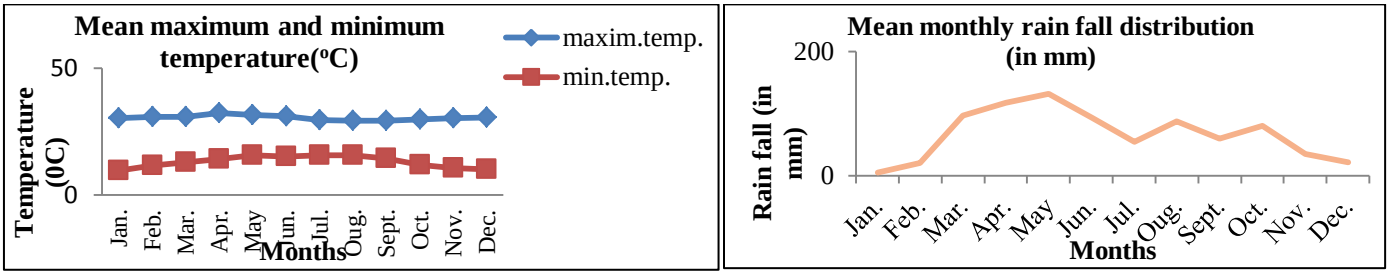

Figure 2. Mean maximum and minimum temperature (ºC) (left side) and mean monthly rainfall distribution (right side) recorded in Babile over 2002 -2016 (Source: NMSA data from 2002 to 2016)

The Babile district total human population was 115,229; of which males (57,463) and females (57,463), and 90,415 (78.5%) were the rural population (Table 1) (FDRE/CSA, 2013). During this study, there was no population census counted for two decades (i.e., in 2005 and 2015) (Table 1). However, there were some projections between (2014-2017) by (FDRE/CSA, 2013). The density of population projected in the district was 36.4persons/km2; which was doubling in the year 1990 (i.e., 18.9 pers./km2). Even, the rural density population in the projection years was (28.53pers./km2), which was doubling the rural population density in 1990 (i.e., 14.13pers./km2) (Table 1). In general, there was unevenness in population distribution due to the result of the differences in the suitability of a given area for settlement and socioeconomic besides historical factors. The increased population led to an increment in the demand for natural resources, such as arable land, water, wood for construction, and energy (firewood and charcoal), and might lead to the expansion of human settlement inside or nearby the boundary of the sanctuary.

Table 1. The Human population size of Babile district (Source-EHPEDO, 2004 and CSA, 2013)

Year	Area	Population			Area (km^2)	Density (person/km^2)
		Male	Female	Total		
1990	Rural	22785	21985	44767		
	Urban	5334	5450	10784		
	Total	**28118 (50.6%)**	**27435 (49.4%)**	**55553 (100%)**	**3169.06**	**18.9**
1995	Rural	35462	34214	69676		
	Urban	6088	6330	12418	**3169.06**	**26**
	Total	**41550**	**40544**	**82094**		
Population Projection (2014-2017)	Rural	45,552	44,863	90,415		
	Urban	12,214	12,600	24,814	**3169.06**	**36.4**
	Total	**57,766**	**57,463**	**115,229**		

The farming system is mixed farming. It is the main source of livelihood, which is mainly characterized by crop production and livestock husbandry (i.e., subsistence agriculture). The majority of crops (either cereal and/or cash crops) were produced by rain-fed agriculture. And, some vegetables, fruits, and cereal crops like maize (*Zea mays*) and Lowiz (*Arachis hypogea*) were also produced (in some places) by the irrigation system, following the Errer and Gobele valleys. Similarly, Zelalem Wodu (2007) also reported major cereal crops (sorghum, maize, pulses, and oilseeds haricot bean, "selit", groundnut, "Chat", and other fruits and vegetables (papaya, guava, mango, sweet potato, tomato, and pepper) were mainly produced (through rain-fed and some in irrigation system). Other than crops, livestock such as camels, cattle, sheep, goats, donkeys, and poultry as well as oxen fattening were mainly produced. However, some people depend on earnings from off-farm activities such as sales of fuel wood, as daily laborers, traders, and handicrafts. In general, the local peoples who were inside and/or outside (nearby) of the sanctuary were engaged in farm and off-farm activities to make their lives better.

The vegetation of the sanctuary was represented by *Acacia commiphora* woodland, semi-desert scrubland, and evergreen scrub ecosystems (Stephenson, 1976) and with high endemicity of various plants and grasslands (Yirmed Demeke *et al*., 2006). Due to altitudinal variation effects, rainfall variability occurred and a marked effect on the vegetation is observed (Yihew Biru and Afework Bekele, 2012). The vegetation of BES is divided into two major categories of riverine and woodland vegetation (Stephenson, 1976; Yirmed Demeke *et al*., 2006). However, presently due to anthropogenic/human-induced/factors (e.g.,

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deforestation), most of the woodland configuration/structure/ has been converted to bushlands (e.g, in most parts of Fedis district/Anani PA). The riverine, woodland and bush lands' distinct habitats are presently observed in the sanctuary. The riverine vegetation that occurred in the sanctuary has a dense stand in the valley bottoms and has a poor composition (i.e., sparsely distributed) away from the valley floors. Most of the riverine vegetation occurred around the Errer valley than the Gobele valley. However, some riverine vegetation was observed in Gobole valleys. Similarly, Anteneh Belayneh (2006) reported that, in the upper Erer, there is a dense stand found in the narrow stripe from the northern boundary to the south for about 25 km as far as and some of this type of vegetation was observed in Gobele Valley. In general, presently the riverine vegetation like the woodland vegetation decreased in structure and composition due to the cutting of trees (e.g., around Errer valley, in Ere ebada and Gamachu local areas), and high charcoal production and severe excavation of sand also observed in the area (e.g., in Fedis and Midhega tola district boundary, around Gobele river, located in the east and west of it). The woodland vegetation in the sanctuary was dense and widely distributed in the valley bottoms while it is sparsely distributed and low in composition as one moves southwards. In most areas, more open woodlands, between the Gobelle and Erer Valleys existed and it provides food and shelter for elephants in the sanctuary. Various tree species have occurred in the sanctuary even though the composition is less compared with shrubs. For instance, *Acacia tortilis*, *Acacia seyal*, *Acacia zanzibarica*, *Tamarindus indica*, and *Acacia clavigera*, were the main tree species observed in the Upper Dakata (Demel Teketay, 1995). While in the semiarid areas, some drought-tolerant species like *Acacia mellifera* and *Acacia nilotica* are highly chosen by elephants and used as a food regularly (Demel Teketay, 1995). Presently some of the woodland vegetation around upper Gobele Valley was changed to Bushland (for instance, in fedis district/Anani PA, intensive charcoal making and tree cutting in the area were noted during field observation with key informants).

The sanctuary's floristic composition mainly consists of shrubs and trees. In the sanctuary, shrubs have accounted for 94.9% while trees constituted only 5.1% of the total density (Tahir and Yeneayehu, 2017). Similarly, Anteneh Belayneh and Sebsebe Demisew (2011) also reported that shrubs accounted for 95.7% of the total density while trees consisted of only 4.3% of its population. Its floristic composition, consists of (10) families, (21) genera, and (39) species respectively, and about 22 plant species that are favorable food for elephants were observed in the sanctuary (of which; *Acacia mellifera* and *Acacia nilotica* are the best-preferred species for browsing) (Anteneh Belayneh and Sebsibe Demissew, 2011). In general, shrubs are the major components of the floristic composition and that can be available elsewhere in the sanctuary.

The faunal composition in the eastern part of Ethiopia is significantly high. Different wildlife species of mammals, birds, and reptiles that are adapting to the semi-arid environment have existed in the sanctuary. The mammals of BES were grouped into 59 species, 51 genera 30 families, and 11 orders (Leonid *et al*., 2010) Mihret Ewnetu *et al*. (2006) also described, that there are 30 mammals and 191 birds species present in the sanctuary. The large mammal species that occurred in the sanctuary were the African elephant (*Loxodonta africana*), lion (*Panthera leo*), leopard (*Panthera pardus*), spotted hyaena (*Crocuta crocuta*), bat-eared fox (*Otocyon megalotis*), black and white colobus monkey (*Colobus guereza*), hamadryas baboon (*Papio hamadryas*), aardvark (*Oryctero pusafer*), Menelik's bushbuck (*Tragelaphus scriptusmeneliki*), bushpig (*Potamochoerus larvatus*), common bushbuck (*Tragelaphus scriptus*), lesser kudu (*Tragelaphus imberbis*), greater kudu (*Tragelaphus strepsiceros*), oribi (*Ourebia ourebi*) and Salt's dik-dik (*Madoqua saltiana*). Salt's dik-dik is the most numerous (Yirmed Demeke *et al*., 2006). BES is one of the 73 important bird areas of Ethiopia (EWNHS, 1996). Birds have occurred more than other faunal groups in the sanctuary. This sanctuary supports the endemic Salvadori's serin (*Serinus salvadorii*), which is only restricted in the eastern lowlands and the Black-winged lovebird (*Agapor nistaranta*) is endemic (restricted only in Ethiopia and Eritrea), which is confined to the highland vegetation in the northern section of the sanctuary (EWNHS, 1996). Generally, about 191 bird species, comprising 17 orders and 51 families were documented (Hillman, 1993; Yirmed Demeke *et al*., 2006). The African rock python (*Python sebae*) and some unidentified snake species, agamas, geckos, and skinks are found in BES. Other species of wild animals (such as reptiles, amphibians, and other smaller vertebrates and invertebrate animals) are not studied even though they are present. In general, Eastern Ethiopia supports a high diversity of wildlife species (mammals, birds, and reptiles), which are adapted to the semi-arid environment.

The geological structure of the sanctuary is composed of Precambrian complexes, Mesozoic-Tertiary sediments, and upper Tertiary-Quaternary complexes (Mohr, 1964). The Precambrian complex underlies all recent rocks, which occurred especially in the central and eastern parts of Ethiopia. The important rocks in the sanctuary are exposures of silicate-chlorite quartzite, magnetite-quartzite, and graphitic quartzite, which all are metamorphosed, and of an igneous and sedimentary origin. The younger rocks are composed of mainly mudstone, salty sandstone, quartzite with black limestone, and dolomite. The area is surrounded by characteristic rocky hills. Mohr (1964) observed that limestone, sandstone, gypsum, marbles, and anhydrite are essential geological settings and the physical and chemical compositions of soils are important for the growth, diversity, and distribution of plant species. Even, the type and texture of soil also influence the distribution of plant species, thereby indirectly affecting the distribution of animals in that particular area (Holdo and McDowell, 2004). In general, According to the Soil Research

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Department of Haromia University, the total area of Babile district is covered with (10%) black soil, (2%) clay soil, and (88 %) clay loam soils respectively (Yirmed Demeke *et al*., 2006).

2.3. Methods

2.3.1. Elephant Population and Age Structure

2.3.1.1. Elephant Population

Reconnaissance surveys were carried out during May 2019 (between 14/05/2019-21/05/2019) for ecological studies. During the reconnaissance surveys, discussion with concerned individuals at the sanctuary and local experts, information on elephant's movement patterns, the availability of dungs (i.e., the place where elephants frequently occurred), and vegetation types (including riverine, woodland, and bushland) habitats were selected for these study. Several sampling methods can be used to estimate the elephant population (such as aerial census, vehicle survey, foot survey, and count). However, the dung count using the line transect technique is the most commonly used method for estimating elephant numbers (Dawson and Dekker, 1992; Barnes, 1993; Morrison *et al*., 2002). The line transects method is preferred due to less biased estimates and has a lower standard error (Burnham *et al*., 1985). Based on the field survey, stratification and transects were laid out by considering the vegetation nature of the sanctuary. Therefore, the three types of vegetation components of the sanctuary (i.e., riverine, woodlands and bushlands) were selected for the study following the habitat use pattern of elephants (e.g., considering the place where elephant's movement occurred more and stay in areas). While selection, key informants and other local peoples have participated since they knew the areas well. In general, seven sites from four districts were selected through the purposive sampling technique (Muchaendepi *et al*., 2019). Among those: two sites were in Babile district (Erer Ebada PA-25km and Ebada Gamachu PA-29km had sight distance from Sanctuary office) were selected for riverine vegetation; the other two sites were in Mayu district (Aloola PA-90km and Gabbibda PA-100km had sight distance from Sanctuary office were selected for woodland vegetation; and three sites were from Fedis district (i.e., two of them from Aneni PA of kontomu -45km and Aneni PA of kere gobele-55km had sight distance from Sanctuary office) and Midega Tola district (i.e., Bilusuma PA-85km distance far from Sanctuary office) were selected for bushland vegetation. From the total area of 1605km^2, 42km ^{2} areas (i.e., each 12km2 from riverine and woodland habitat while 18km^2 from bushland) were purposively sampled. By considering the place where good habitat, observation of many elephant dungs, and elephants where more stay in the areas compared with non-sampled areas was noted by key informants and rangers during a preliminary survey. Transects were allocated in proportion to the approximate dung pile densities in all three land units. Among the total of 21 transects (i.e., each having 3kmlength), 6 transects were lined in the riverine habitats which were approximately perpendicular to the baselines of the left and right of Erer river. The starting point of the first transect was randomly selected and placed at a 1km regular interval in every three habitats of seven sites. Each transects holds seven quadrants (each having 30 m by 30 m and 500m equidistance). In general, from a total of 21 transects, 147 quadrants or box plots along the transect were laid to study the elephant population through a dung survey. Distance between transects and along transects (for instance, between quadrants) was measured through a tape meter and distance was walked alternatively. To complete the transect survey, a total of 77km length of transect were walked (63km along transect and 14km between transect) between 4 September and 18 October 2019. During this time, the observed dung piles were counted and recorded following the typology of the dung morphology (Barnes and Jenson, 1987; Barnes, 1996). While collecting dung piles, the observer walked slowly down the center-line of the transect searching for it in each quadrant along the transect. Different dung morphological characteristics like intacted boli, very fresh, moist with odor and without odor, fresh but dry, disintegrated, and amorphous shapes were observed. In general, the dung count method requires a translation of the data into the number of elephants. Besides, data on an estimated population size of elephants between (1970) and (2021) in the sanctuary were also compiled for comparison.

2.3.1.2 Estimating Dung-Pile Density (Dung-Piles Per Km2)

The dung piles were marked using numbered bamboo sticks for continuous monitoring (Dawson and Dekker, 1992; Barnes, 1996). The dung piles were revisited for the first three consecutive days and then weekly till they disappeared (Dawson and Dekker, 1992). The morphological stage of the dung piles was noted as A, B, C, D, and E (Barnes and Jenson, 1987 and Barnes, 1996) (Table 2). The time of decomposition for dung piles was taken as the period from the date of identification of the dung piles to the last time that was seen at stage D. Dung piles observed while walking the transects were identified, counted, and aged using the categories described in (Table 2). The observer walked along the center-line of the transect. Whenever a dung pile was spotted, the perpendicular distance of the dung pile from the line transect was recorded. Some dung piles, especially those further from the centerline, may not have been seen at all. Dung piles were classified according to their shape, i.e., the probability of being seen from the center-line of the transect. From the total of 727 dung piles surveyed; only dung piles in categories A- D (i.e., 710 dung piles) were used to estimate dung-pile density. About 17 dung piles were very decayed and not detected within a 2m radius from the centerline (Table 2) (Appendix I. Table 1).

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Table 2. Dung piles categories based on the condition of the dung

Categories	Description
A	Boli intact, very fresh, moist with odor
B	Boli intact and fresh but dry, without odor
C	Some of the boli have disintegrated, others are still recognizable as boli
D	All boli get disintegrated, dung piles now form an amorphous flat mass
E	Decayed to stage not detected at arrange of 2 m from the centre line

To estimate the total dung pile densities, the program ELEPHANT was used. The lines transect sampling technique developed by Burnham *et al.* (1985) was used to estimate dung density. A file containing the data on perpendicular distances was developed (Appendix I: Table 2). The program reads this file and uses the perpendicular distances of dung piles to calculate f (O). Using the steady-state assumption, the density of dung-piles, Y, was calculated as:

$$Y = \frac{n.f(O)}{2L}$$

Where n = the number of droppings
L = the total length of the transects
f(O) = an estimate of the reciprocal of the effective strip width
The data for each habitat were analyzed separately and finally combined to give an overall estimate for the whole study area following the work of Barnes *et aI.*, (1995) and Norton Griffiths (1978).

2.3.1.3 Estimating Defection Rate (D)

The defecation rate is defined as the average number of dung piles produced per elephant per day (Barnes and Jensen, 1987). It is determined by following a known number of elephants usually for about 12 hrs and recording all droppings (Tchamba, 1992). From these data, it is possible to calculate the number of dung piles per elephant per day. During the study period, it was impossible to carry out fieldwork on the defecation rate in the study area. This is because of the frequent mobility of elephants due to high hunting pressure. Several field workers have estimated different values for defecation rate (Coe, 1972; Merz, 1986; Tchamba, 1992). In this study, the figure, which was based on several observation hours, of Tchamba (1992), D = 19.77 dung-piles per elephant per day with SE of 0.23, was used for the dry season data analysis.

2.3.1.4 Estimating Decay Rate (r)

The decomposition of elephant droppings can be estimated by monitoring dung piles until they disintegrate i.e. until they pass from morphological stage D to stage E (Bames and Jensen, 1987). In the field, dung piles can be classified in one of the five categories, A-E, according to their shape and state of existence. To cany out this fieldwork, the area was searched regularly for 50 sample fresh dung piles of various sizes from areas with different vegetation types and recorded from the eastern and central areas of the park. Each dung pile was measured, marked, mapped, and then monitored weekly until it disappeared.
The percentage for the daily decay rate was calculated by Bames (1992) as:

$$r = \frac{\ln (No) - \ln (Nt)}{t}$$

Where:
No = initial number of droppings
Nt = numbers left after t days
r = rate of decay; t = number of days; Using this calculation the mean decay rate of elephant droppings in the BES for the dry season was 0.009 (SE=5.6). Then the number of elephants present in the BES during the dry season was estimated by the equation.

Data Analysis: Densities of elephants were estimated using the ELEPHANT program recommended by (Dawson and Dekker, 1992; Barnes, 1996) was used to analyze dung pile densities. It converts the dung pile density into elephant densities by involving the defecation rate, dung decay rate, and dung pile density for the total area.

2.3.1.2. Population Age Structure

Elephants were grouped into five age groups (Lee and Moss, 1995; Moss, 1996); Calf (< 1 year old), Juvenile (1< X < 4 years old), Intermediate (4 < X < 9 years), Sub-adult (9 < X < 15) and Adults (> 15 years) (Williams, 2002). Aging of the elephant population of the study area was conducted based on the body size comparison (Lee and Moss, 1995; Moss, 1996), hind footprint length (Western *et al.*, 1983), and dung piles circumference (Jachmann and Bell, 1984b; Morrison *et al.*, 2002). Elephants grow

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throughout their lifetime (Hanks, 1979; Moss, 1996). The larger an elephant is, therefore, the older its age. The body size comparison was done relative to the height of an adult female elephant in the group. Calves beneath the front legs of the adult female; juveniles are those passing under the throat; intermediates have a height below the eye and sub-adults are having a height above intermediates but below the adult female. Adult males are those having a height greater than the adult females in the group (Manspiezer and Yilma Delellegne, 1992). Footprint length was measured from the outer edge of the wrinkled imprint to the middle of the toenail of the hindfoot. According to Western *et al*. (1983), based on footprint length, the aging class of elephants can be also determined; the footprint lengths of less than or equal to 21.8cm grouped as calves, between 21.8 and 27.2cm grouped as juveniles, between 27.3 and 33.7 grouped as intermediate, between 33.8 and 44.1 cm grouped as sub-adult male or adult female and footprint length greater or equal to 44.2cm grouped as adult males.

Data Analysis: In general, the data was analyzed by measuring and counting the number of footprints lengths that were observed in the all study sites, and by adopting the Western *et al.* (1983) footprints length category (i.e., to estimate elephant age class), were used to estimate the population age structure.

2.3.1.3. The Movement Pattern and Seasonal Distribution

The movement pattern and dry and wet season distribution of elephants were studied based on footprints, dung piles, and feeding signs (Whyte, 1996). The data was collected from a questionnaire survey and discussions with key informants. Information about habitat type was recorded on the notebook and the routes were recorded using GPS. .

Data Analysis: The GPS recorded routes were marked on a geo-referenced map of the area using a GIS program, such as Arc map10.8 versions, which was applied to estimate the movement pattern of elephants and enable us to compare with previous studies. The GPS data was placed on a geo-referenced map and the past and present movement patterns or distributions of elephant's routes were identified.

3. RESULT AND DISCUSSION

3.1. Population Estimates

3.2. Population Estimates

Indirect counting of elephant population numbers was estimated by considering the elephant dung piles circumference, density and stage of decay. A total of 727 dungs were counted in BES (Table 3a). Specifically, from a riverine habitat 283 dungs, woodland habitat 118 dungs, and bush land habitat 326 dungs were counted; and also recorded with their respective GPS coordinates (Appendix I: Table 1). From, the stage of dung decay, 172 (23.65%) were fresh dungs that were moist with odor, 89 (12.24%) dungs were intact and fresh but dry without odor, 266 (36.6%) dungs of some parts were the boli get disintegrated, 183 (25.17%) of dungs were their boli get disintegrated to form an amorphous flat mass, and 17 (2.34%) of dungs were decayed to stage not detected at arrange of 2 m (Table 3a). More than (60%) of the average total dung pile circumference was recorded in both Erer ebada (62.72m, 35.26%) and Gamachu (44.48m, 25%) sites respectively. However, 1/4th of the availability of dungs and more than (60%) of the average total dung pile circumference were observed in Bilisuma site than all others (Table 3a).

Table 3a. Estimation of elephants average dung density, dung pile circumference and stage of dung decay in BES

Study sites	Transects no.	Quadrants no.	Dung quadrants	Total no. of dungs	area (km^2)	Dung density (dungs/km^2)	Dung pile circumference (m)		Stage of dung decay				
							ACDP	TACDP	A	B	C	D	E
Gamachu	3	21	14	139	6	23.17	0.32	44.48	-	-	89	41	9
Erer Ebada	3	21	17	144	6	24	0.37	62.72	55	35	29	25	-
Gabibda	3	21	19	57	6	9.5	0.39	26.6	-	-	21	36	-
Aloola	3	21	17	61	6	10	0.28	17	-	-	36	25	-
Anani (Gobele)	3	21	5	14	6	2.33	0.15	2.1	-	-	5	2	7
Anani (kontomu)	3	21	19	132	6	22	0.27	37.51	-	-	77	54	1
Bilisuma	3	21	13	180	6	30	0.42	86.99	117	54	9	-	-
Total	**21**	**147**	**104**	**727**	**42**	**111.10**	**1.63**	**177.9**	**172**	**89**	**266**	**183**	**17**

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Note: Stage of dung decay observed (A= Very fresh, moist with odor, B= Intact and fresh but dry without odor, C= some of the boli get disintegrated, D= all boli get disintegrated to form amorphous flat mass and E= decayed to stage not detected at a range of 2 m) by adopting Barnes and Jenson (1987) and Barnes (1996). ACDP= Average Circumference of Dung Pile, TACDP= Total Average Circumference of Dung Piles,

In general, about 70% of the sampled quadrants were consisting dungs; however, 30% of it was an absence of dungs. Out of which; 76.2% of sampled quadrants in the Anani (Qare gobele) bushland site was observed/recorded as the absence of dungs and it covers about 11 % of the total sampled area (Appendix I: Table 1). The average dung density was highest in bilisuma site (i.e., 30 dungs/km^2) relative to other sites (Table 3a). However, fewer distributions of dungs in Anani/Qare gobele area (< 3dungs/km^2) were observed. Moreover, high dung density (i.e., nearest numbers of dungs) were also recorded in Erer ebada (24 dungs/km^2), Gamachu (23 dungs/km^2), and Anani/kontomu (22dungs/km^2). On contrary, medium numbers of dung density were noticed in Alola and Gabibda study sites (10 dungs/km^2) (Table 3a).

Table 3b. Dung pile density and elephant number estimation in the three habitats of BES

Habitats	Stratum area (Km^2)	No.of transects	Length of Transects (km)	Sampled area (km^2)	Number of dropping (sampled area)	Dropping Density (stratum)	Elephant density (Eleph./km^2)	Elephant number
Riverine	308	6	18	12	274	22.83	0.285	88
Woodland	610	6	18	12	118	9.83	0.063	38
Bushland	687	9	27	18	318	17.67	0.152	104
Total	**1605**	**21**	**53**	**42**	**710**	**(x=16.77)**	**(x=0.16)**	**230**

From the above three land units of dung piles survey, the estimated total calculated mean decay rate was 0.0085 (SE= 5.4), the defection rate was 19.75 droppings per elephant per day, and the mean dropping density was 710 dropping per habitat for the dry seasons were observed (Table 3b). 17 dungs were not detected within 2m; due to amorphous shape and scattered dungs features (Table 3a). Hence, it was not included in the density of dung piles to estimate the elephant population (Table 3b). Dung-pile visibility was limited by the nature of the vegetation. However; in this study, there was no problem with the invisibility nature of dung piles were observed unless/otherwise the decayed dungs which were distributed, not easily detected within 2m by the naked eye. The maximum recorded visible distances and the maximum mean sighting distance from the center lines were 5.05, 5.5, and 5.5ms and 3.55, 4, and 5.25ms for the riverine, woodland, and bush land habitats respectively (Appendix-I: Table 2). The total estimate for the elephant population for the whole study area was 230±20 (210 to 250) (mean (X) =230; SD=20). The observed density for the whole sanctuary was (0.033elephants/km2). This finding supports earlier data suggesting that BES supports a small number of elephants: Sintayehu *et al*. (2016) estimated 237 elephants; Belayneh *et al*. (2011) estimated 250 elephants, and the estimate of Yirmed Demeke (2008) was 264. For instance, different guesses were suggested by the sanctuary staff (less than 300 elephants might occur in the sanctuary), all other previous estimates (Yirmed Demeke, 2008; Belayneh *et al*., 2011; Sintayehu *et al*., 2016) and this study suggest that similar population decline has been observed as well. It is not possible to compare the above estimates directly, as they used different survey methods (i.e., aerial/on foot). However, we can say whether the population increases, decreases, or remains stable by analyzing the extent of poaching and the number of elephants counted in several herds.
In this study, to compare the indirect and direct census of elephants (i.e., on foot), both methods were carried out. However; while direct census of elephants, elephants were observed only in one of the selected sites (i.e., Ebada Gamachu). During this time, the observed elephant population were having a value of (Mean (X) =75, SD =7.07). So, it is difficult to estimate the elephant population that was not observed in the other selected sites. Hence, the indirect method of counting elephants through dung counts was preferable and was used to estimate the elephant population due to dungs being observed in all selected study sites. As shown in Table 4, the number of elephants in a herd during the study period was small (maximum of 75) compared to the previous records (the maximum of 264 in 2006, 250 in 2011, and 237 in 2015). Therefore, the few elephants that were observed along the track and paths of the sanctuary imply that there has been a serious decline or low population and range (Table 4). Comparison of elephant sightings between (1970) and (2021) and present studies as indicated in (Table 4) below.

Table 4. Estimated population size of Elephant between (1970) and (2021)

Year	Population estimate			Specific site	Survey method	Source	Remark
	Min.	Max.	Average				
1970-1975	-	-	-	-	-	-	No data available
1976			600	BES	Aerial	Stephenson, 1976	Countedin 1976/1977
1977-1985			-	BES	-	-	No data
1986			300	BES	Aerial	Yalden *et al*., 1986	Counted in 1986/1987
1987-2005			-	-	-	-	No data

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2006			264	BES	On foot	Yirmed Demeke,2008	Counted in 2008/2009
2007	-	-	-	-	-	-	No data
2008	-	-	-	-	-	-	No data
2009	-	-	-	-	-	-	No data
2010	-	-	-	-	-	-	No data
2011			250	BES	On foot	Belayneh *et al*., 2011)	Counted in 2010/2011
2012	-	-	-	-	-	-	No data
2013	-	-	-	-	-	-	No data
2014	-	-	-	-	-	-	No data
2015	213	261	237	BES	Aerial	Sintayehu *et al.*, 2016	Counted in 2014/2015
2016	-	-	-	-	-	-	No data
2017	-	-	-	-	-	-	No data
2018	-	-	-	-	-	-	No data
2019	70	80	75	Ebada gamachu	foot	Taye Lemma,2019	Counted in 2019/2020 during the study
2020							_
2021							_

Note: Elephant sighting record starting the sanctuary establishment year of 1970.

3.3. Age Determination

In this study, based on the dung-pile circumference droppings, the ages of elephants were estimated. According to the result, More than 47% of dungs were having circumferences between 32 and 43.7cm (Table 5a) and a very less number of dung piles (2.34%) were having circumferences between 44.7 and 51.2 cm (Table 5a).

Table 5a. Dung pile distribution and its circumferences in the seven study sites of BES

Study sites	Distribution of dung pile (cm)					Total dungs
	≤ 20cm	20.5 cm -31.8cm	32cm-43.7cm	44.7cm-51.2cm	≥ 52.5cm	
Gamachu	5	-	125	-	-	130
Erer Ebada	-	16	88	-	40	144
Gabibda	-	11	26	-	20	57
Aloola	48	-	-	5	8	61
Anani (gobele)	7	-	-	-	-	7
Anani (kontomu)	34	66	19	12	-	131
Bilisuma	35	-	80	-	65	180
Total	**129**	**93**	**338**	**17**	**133**	**710**

Age structures of elephants were determined through Age category and dung pile circumferences were adopted following Williams (2002) and Morrison *et al*. (2002) (Table 5a) (Figure 3). The majority of the population was grouped under intermediate followed by adult males and calves age class (Figure 3) (Table 5a). However, sub-adult males and females were very few (Figure 3).

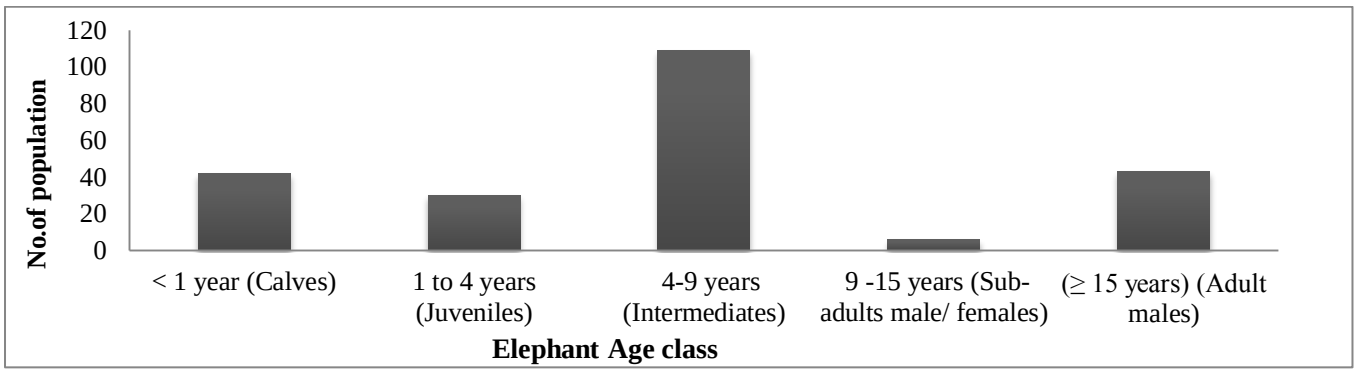

Figure 3. Age structure of Elephants in BES based on dung pile circumference

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Table 5b. Percentage of Age structure from dung pile circumferences

Elephant Age class	Percentage
Calves	18.26%
Juveniles	13.04%
Sub-adults male and females	2.6%
Intermediates (young/medium adult)	47%
Adult males	19.1%

In this study, direct counts, sexing, and aging were difficult because of the animals' nocturnal habits (i.e., occurring at the night), large area coverage, occurring at a remote distance, and some dense vegetation. Particularly, during the wet season, the encroachment of people in the sanctuary was high for practicing agricultural/cultivation activities. Due to this, elephant movements were restricted during the night in the woodland and bushland habitats. This probably has made challenging for observing elephants during the daytime.

3.4. Population Trends and Sanctuary History

BES sanctuary was established in 1970 by Emperor Haile Selassie to conserve the relic and fragmented population of Elephants (i.e.,*Loxodonta Africana* Sub.spp.*orleansi*). As a key informant interview, before the establishment of Sanctuary in 1970, Emperor Haile Selassie was visiting the area and informed there was indiscriminate hunting of Elephants and Lions in the area. Before the Imperial decree, the site was called a controlled hunting area and served for sport hunting of Elephants and Lions. There is also an illegal hunting expansion in the area before the foundation of the sanctuary and Elephants in particular were hunted for their valuable ivory. This ivory was transported to Somalia and Djibouti and shipped out to various Arabian and Asian countries (BESDMP, 2010). Haile Selassie's decree arrested all former hunting and made the way for the establishment of the Sanctuary. The sanctuary boundaries were defined using natural features including valleys and escarpments. A small office with few scouts was also placed first in Harer town and later moved to Babile town to oversee conservation and development work. Beyond these initial establishment and staff allocation tasks, there are also a few major conservation practices like patrolling takes place. The sanctuary supports the most significant elephant population in Ethiopia. However, the dramatic loss of the species, its habitat, and open access to poaching for their tusks have become the major causes for the decline of elephant numbers and their home ranges.

During the early establishment in 1970, more elephant populations were observed and probably this showed that as there were less encroachment occoured in the sanctuary (Figure 4). As key informants replied, elephants were kept or herded with camels, and also moves to the main road sometimes. Different scholars have reported the population of elephants in the sanctuary. Among those; the Elephant population numbers were 300 in 1986 (Yalden *et al*., 1986); 264 in 2006 (Yirmed *et al*., 2006); 237 in 2015 (Sintayehu *et al.*, 2016) (Figure 4). After 1970, the sanctuary populations were declined. The worst decimated population was between 1970 and 1986 (which is about 300 population were declined). After 1986, the population were declined until the present study (230+20) (Table 4) even though; the rate was not as much higher as between 1970 and 1986 (Figure 4). In this study, Analysis of long-term elephant population census data (i.e., over 48 years) showed that the population of the elephant was declined (Figure 4). Besides, key informants were interviewed, and they responded as there were HEC and affecting their agricultural lands. Similarly, Sintayehu and Kassaw (2019) reported that about 85% of the respondents were aware of HEC issues and 43% of them also encountered elephants in their farms at least once in the past 40 years.

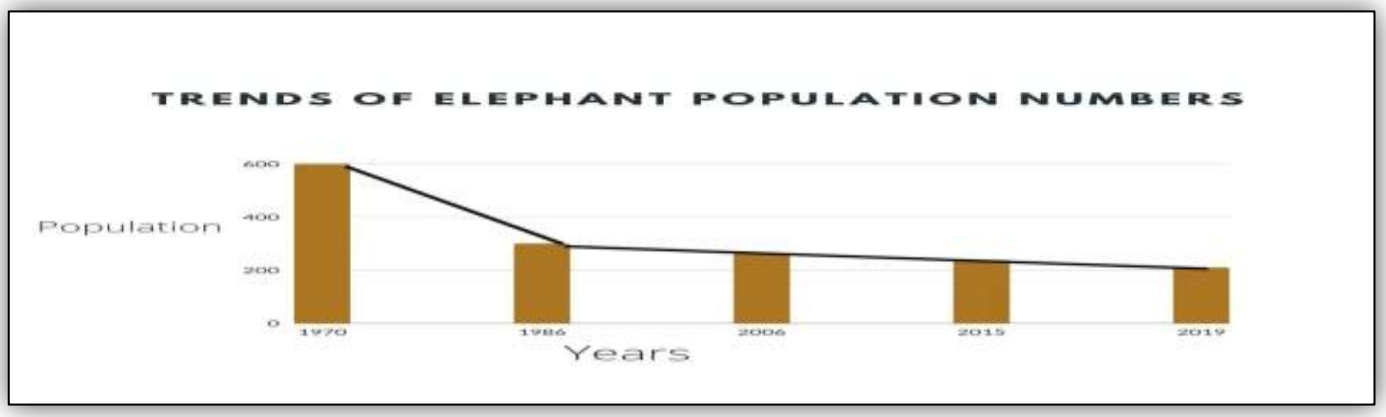

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Figure 4. Elephant population trends in the Babile Elephant Sanctuary ecosystem from 1970 to 2019. Source: Stephenson 1976; EWCO 1990 (Yalden *et al*., 1986; Yirmed *et al*., 2006; Sintayehu *et al*., 2016; and present study)

3.5. The Past Movement Pattern of African Elephants in BES

The past and present movement patterns or distribution of elephants in BES were possibly identified. Based on interviews with the local peoples, elephants used to be occupied in the past following the four main drainage river valleys (Fafem, Daketa, Erer, and Gobele) rise from Garamuleta-Gursum highlands, and these extend southwards through the sanctuary to join Wabi Shebelle River Basin (Figure 5).

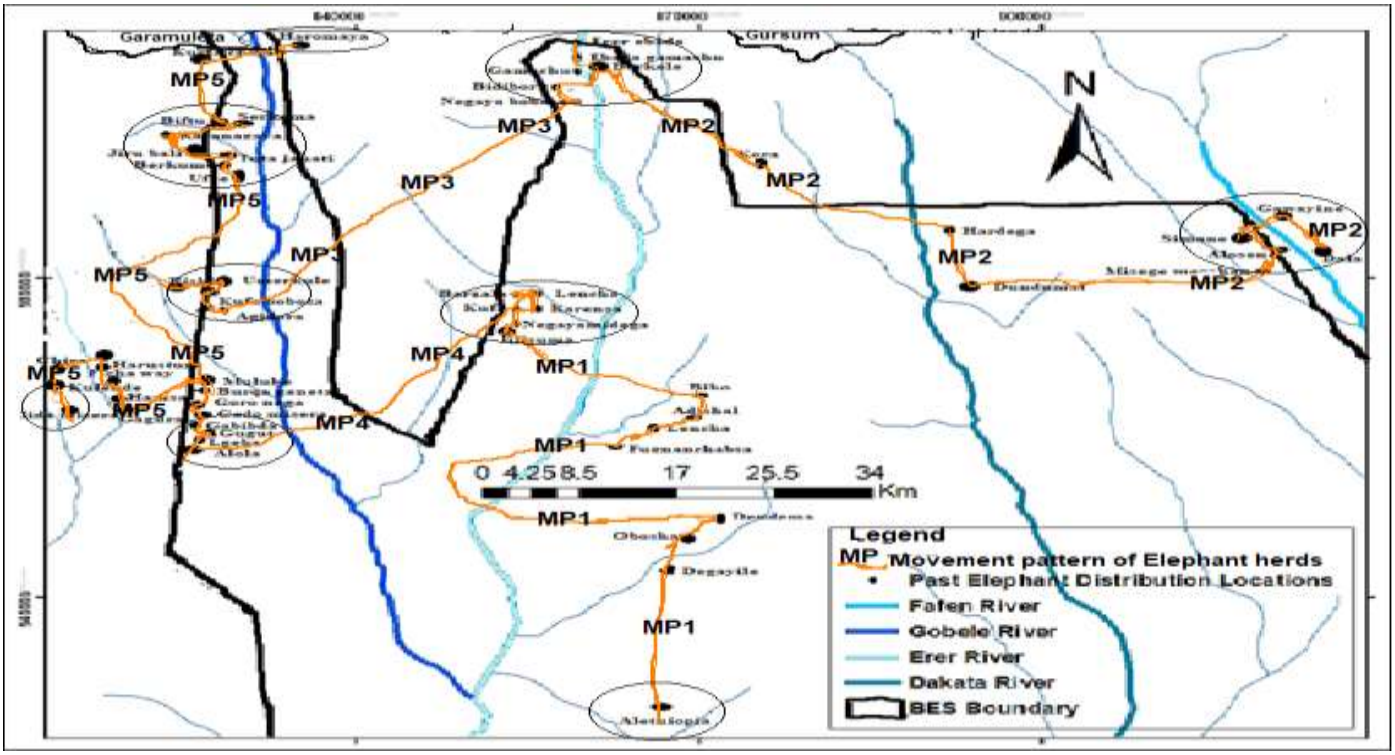

Figure 5. Past distribution of elephants in Babile Elephants Sanctuary

According to local people, before the establishment of the sanctuary (i.e., in 1972) and many years back, elephants were moved here and there, and visible along the roads (Figure 5). There were five to six different herds of elephants movement patterns were occurred in the past between Oromia and Somali regions. The first Elephant movement pattern was along the route of the Somali region of Alethiopia and Bikko, and also move to the Oromia region of Midega tola district of Bilisuma PA and other villages (Figure 5). The Second route movement direction based on local peoples were, from outside east of the present sanctuary site boundary of Dala areas of Somali region to the southwest direction passing various areas and move to Kora site and finally moved to Oromia region of Babile district of various villages of Erer Ebada, Ebada Gamachu and Berkele PAs and other surroundings (Figure 5). The third, fourth, and fifth routes were estimated in the Oromia region. The third group's movement estimated routes were from Babile district areas of Erer Ebada, Gamachu Passing through Bidibora and Nagaya Bobasa areas to the Fedis district areas of Agidora, Riski, and Umerkule and some Kufa Bobasa district areas along the same routes (Figure 5). The fourth route movement was estimated, from Mayu Muluke district areas of Alola and Gabibda areas to Midhega tola district areas of Karensa, Barzala, Lencha, Negayamidhega, Kufa, and Bilisuma areas (Figure 5). The fifth pattern extends a large area from above Grawa district nearby Garamuleta highlands moving up into in the east direction outside the sanctuary to Haramaya district and the same groups also passing the same routes moving down into Kurfa chale district areas of Dire gudina and Grawa district areas of Rasa Nagaya, Ufe, Serkema, Tuta janati, Jirubali, Biftu, Berkume, and nearby villages and Moved downward again to Mayu Muluke district areas of Alola, Goronaga,Burkagenet,Gedo misera, Ligba, and Muluke PA areas. Besides, elephants moved outside the sanctuary to the west direction of the sanctuary boundary of Somali region areas of Kulunde, Chira,Jida misera,Gagura, Hamsa,Harustuga, and Fichaway PAs areas and nearby villages (Figure 5). Generally, the past distribution of elephant herds was concentrated along with their respective moving pattern routes back and forth of inside and outside boundary sanctuary areas of both Oromia and Somali regions.

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3.6. The Present Movement Pattern of African Elephants in BES

While this study was carried out, the present movements of elephants were also identified by making interviews with the local people. Two major movements of elephants (one in November 2019 and the other in March 2020) were noted across the sanctuary boundaries. Mostly the movement of elephants presently follows the Upper Erer and Lower Gbelle valley (Figure 6). There was a movement of elephants that occurred in BES and partially migratory in the case of individuals moving far in the southwest up to the highlands of Garamuleta town, in response to the temporal availability of food and water. Elephants were occupied following the Erer Valley (Oromia-Babile and Somali babile/Dhandama district) and Gobele Valleys (Fedis, Midega Tola, Mayu Muluke, and Geraw districts) (Figure 6).

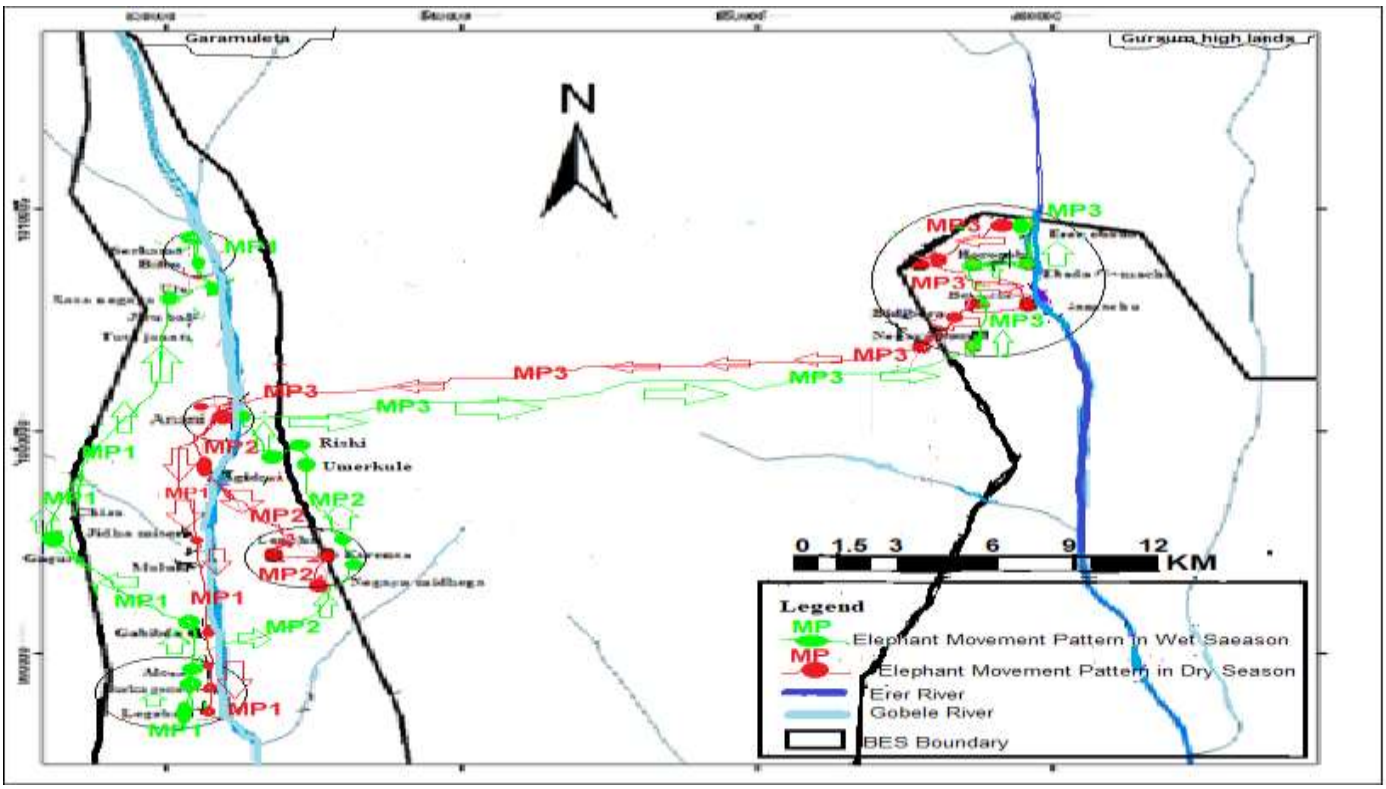

Figure 4.5. Present dry and wet season's distribution of elephants in Babile Elephant Sanctuary

Elephant movement in the sanctuary occurred during wet and dry seasons. During the wet season, elephant movement routes were longer than during the dry season due to feeding resources for elephants being observed in most areas (Figure 6). There are three Movement Patterns (MP) or distribution of elephant's herd's directions observed in the sanctuary both during wet and dry seasons (Figure 6). The wet and dry season moving pattern routes of elephant distributions were designated in green and red color respectively as indicated in (Figure 6) with their specific directions.

3.5.1. Wet Season Distribution

During the wet season (especially between September and October), elephants were observed together in the upper Erer Valley. Mostly during September, elephants moved by crossing the boundary in the north. The first movement journey or patterns were observed from Upper Erer valley to south of the Sanctuary exploring along the tributaries of Erer River and returning north along the same route. The second movement patterns were also observed from Upper Erer to Gobelle Valley from the beginning of October to the first week of January exploring adjacent areas of Gobelle Valley and its escarpments up to the highlands of Garamuleta town. Even, Elephants were observed in the Erer Valley at the beginning of January. During the rainy months of August to November 2019/2020, elephants were observed splitting into smaller groups as soon as the rain starts. During this period, an elephant has a wide distribution and explores all the plain areas of the sanctuary as far as the bases of Gara Muleta Mountain, and associated mountains and ridges. During a wet season, elephant distribution appears to extend outside the sanctuary boundaries (Figure 6). Seasonal movement information on elephant migration was gathered and observations were made. The study shows that elephants in BES are a resident population. However, part of the population occasionally forages outside the boundary of the sanctuary. Specifically, during the wet season, elephants' movements occurred through the large routes (i.e., indicated by green color) (Figure 6). While activities of people in the sanctuary were minimal, as a result of the road inaccessibility for vehicles and difficult to supervise the large area coverage on foot. The movements of elephant's routes were

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mainly from Mayu Muluke district areas of Alola, Gabibda, Burkagenat, and Legba areas inside the sanctuary. Elephants were migrating about 30 km northwest of outside the boundary sanctuary in the Mayu Muluke district areas to the outside part of the sanctuary along with Mayu Somale district areas of Gagura, Jidamisera, Chira, and other village areas (i.e., areas where movement happened) (Figure 6). Elephants move between the North-Eastern escarpments and parallel to Gobelle valleys passing through Alola and Gabbibda villages, and Muluke town (Figure 6) then moving out of the boundary part of the sanctuary which is the peripheral part of the Ethio-Somali region nearby district. The area is dominated by woodland vegetation. Elephants stay here for up to one to two weeks depending on the presence of people. This is one of the sites observed during the study period where elephants move outside the sanctuary. While other herds of elephants passed to the Grawa district areas of Ufe, Rasanagaya, Tutajanati, Jirubali, Berkume, and other nearby villages (Figure 6). Another wet season movement pattern also occurred from Alola areas of Mayu district to Midegatola district areas of Barzale, Kerensa, Lencha, Bilisuma, Nagaya midhega, and Bilisuma areas and move to Fedis district areas of Umerkule, Riski, Agidora, Anani and then nearby areas of Fedis district to Babile district (i.e., Dibora, Negayamidhega, Sirba and Kufa bobasa areas) and Areas of Ererebada, Ebadagamachu, Gamachu, and some areas of Berkele PAs of Babile district (Figure 6). In general, during the wet season, more coverage of elephant distribution was observed due to more availability of food and water in the sanctuary and around sanctuary boundaries.

3.5.2. Dry Season Distribution

During the dry season period (February to March 2019/2020), scarcity of food, water, and the killing of elephants was frequent and elephants of different herds come together to form large groups. The herds always concentrate in the North and South East entire part of the sanctuary following the Erere and Gobele Valleys. The rivers in these two valleys were only the source of permanent water for elephants and other wildlife species in the dry seasons. These areas were dominated by riverine forests and woodland. During this season, mostly elephants were moving from Erer Valley of Babile district areas, Ererebada and Gamachu PAs villages to nearby Fedis district areas of Sirba, Nagayabobasa, Kufabobasa, and moves to Anani PA areas of the same district (Figure 6). Again from Anani site most probably be moved either to Midegatola district areas of (Lencha, Nagayamidiga, and Bilisuma PAs villages) or moved passing Gobele valley to Mayu Muluke district areas of Alola and Gabibda PAs and associated villages (Figure 6). The present elephant movement is restricted only to Erer and Gobele valley. However, there was no movement of elephants presently occurring in the Somali region. Previously, many years back, movements of elephant herds were observed following the Dakata valley and Fafem river as key informants were interviewed. In general, the present movements of elephants during both seasons were restricted along Erer and Gobele valley due to the other parts of the sanctuary were impacted or encroached by anthropogenic factors. In the sanctuary, it was noted that poachers have come from Djubuti and Somali land besides Oromia and Ethio-Somali region for intensive exploitation of elephants for ivory. Such continuous poaching activities have made elephants to be exterminated from most parts of the sanctuary, especially from the largest part of the sanctuary (i.e., the Ethio-Somali region) to the small portion of the sanctuary (Oromia region). Even at the time of the sanctuary establishment, Elephants were believed to move east of sanctuary Dakata Valley, especially along Fafem River, which was the largest portion of the sanctuary (Figure 6). However, presently most elephants had restricted movement along the two valleys (i.e., Erer and Gobele), beneath districts that were located in the Eastern Hararege Zone of the Oromia region around the sanctuary (Figure 6). In general, in BES, elephant movements were restricted with Erer Valley from the north to south direction of Gobele valleys. According to Yirmed *et al*. (2006), the migratory corridors to the south to Wabe Shebelle Valley were completely interrupted and their movements were restricted only to Dakata Valley in the east and the western escarpment of Gobele River in the west, which were not occupied by agriculture and settlements (Figure 5) and about 82% of the natural range of elephant has been lost since the 1970s (Yirmed Demeke, 2008). However presently their movements were only restricted to Oromia-region parts of the sanctuary (i.e., Erer and Gobele Valleys) (Figure 6).

In general, at present most of the movements of elephants were impeded by progressive settlement and human activities in the sanctuary. From this study, the animal home range was estimated based on the key informants interviewed. Accurate grid references of the location of elephants were mapped and various elephant tracks and feeding signs were noted. Presently movements of elephants mostly occurred in the Oromia side of the sanctuary (i.e., 23% of 6982km^2 of the sanctuary areas) which is estimated to have a home range area of 1605km^2) (Yirmed *et al.*, 2006). Elephants select the most nutritious and palatable plants that are available in high quantities (Westem and Lindsay, 1984). As indicated by Jachmann (1988) the wide distribution of elephants during the rainy season is to overcome nutritional stress and build up new energy reserves. In this study, a poacher's activity, which is very minimal during the rainy period, is another factor in the wide range of seasonal distribution (foraging behavior) of elephants. The size of the home range of an elephant is an indication of the availability of food and water resources and the extent of human disturbances in the surrounding areas. And this is determined by the size of the protected area that the animal is occupying. The estimated home range of elephants in BES (1,605km^2) is relatively larger compared to Kruger National park, Tanzania, which has a mean of 909 km2 (Whyte, 1993) and is relatively large than Mago National Park (MNP) (1,597 km^2) (Yirmed Demeke, 1998). However, in a resource-scarce environment like Namibia, the average size of the home range was

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between 5,860 km2 and 8,693 km^2 (Linde que and Lindeque, 1991). Therefore, the area of the sanctuary is relatively large with some abundant forage and plenty of water. Currently, most of the elephant's home-ranges migratory corridors have become closed and narrowed due to continuous settlement expansion, agriculture, and poaching.

4. CONCLUSSION

Elephants in the BES live in semi-arid bushland, woodland, and riverine forests. So far, the sanctuary is capable of harboring the most viable elephant population in the eastern part of the country. The result revealed, that about 230 elephants population were estimated in the sanctuary. Besides, about 47% of elephants were young/medium adults, 19.1% were Adult females, 18.26% were Calves, 13.04% were Juveniles and a very few (2.6%) of them were sub-adults male and females. In general, there were few elephants were observed in the previous data (300 number, Yalden *et al*., 1986), (264 number, Yirmed *et al*., 2006), (237 number, Sintayehu *et al.*, 2016). Knowing the past and present movement patterns of African elephants in the sanctuary is important to give particular attention to sensitive areas while monitoring the elephant population. Based on this study, in the past, Dakata valley and Fafem river were the largest elephant migration routes that were widespread in the largest part of the sanctuary that was observed in the Somali region. Due to anthropogenic impacts especially poaching, the movement pattern of elephants was changed totally in the direction were mainly following the Erer and Gobele Valley. The wet season elephant movement pattern has following longer routes than the dry season movement pattern. Therefore, the small population of elephants and unclear movement pattern of elephant distributions in the sanctuary might be endangered and easily susceptible to the extinction of the species. Hence, the conservationists need to look into the future in enhancing the value and sustainability of elephants and developing management plans for effective elephant management in the sanctuary.

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DECLARATION

Abbreviations: BES-Babile Elephant Sanctuary, BESDMP-Babile Elephant Sanctuary Draft Management Plan, NMSA-National Meteorological Service Agency, PA-Peasant Association

Competing interest: All the authors do not have any possible conflicts of interest

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Author contribution: All data collection, analysis, writes up of the draft paper was done by the corresponding author while commenting, finalizing, and approving the whole document was by both authors

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Appendix I: Table 1. Estimation of elephant dung count, average total dung pile circumferences, and stage of dung decay occurred in each specific sites of riverine, woodland, and bushland areas of study sites in BES

Representative sites	Specific site	Transects no.	Quadrants (Q) no.	Surveyed (Q)	Observed Dung (Q)	Absence of dung (Q)	Av. Altitude (m)	Representative GPS reading		Total number of dungs	Average d/pilecircum(m)	T/average d/pile circum(m)	Stage of dung decay					Habitat types
								X-coordinate	Y-coordinate				A	B	C	D	E	
Gamachu (Babile district)	Rare digalu	T1	Q1-Q6	6	2	4	1225.8	09º06´.5242"N	042º15´.7800"E	5	0.2	1	0	0	4	0	1	**RH**
	Rare dulach	T1	Q7	1	0	1	1220	09º05´.3018"N	042º15´.8209"E	0	0	0	0	0	0	0	0	**RH**
	Rare dulach	T2	Q8-Q18	11	10	1	1232.3	09º05´.4495"N	042º16´.2869"E	115	0.37	42.55	0	0	73	34	8	**RH**
	Rare dulach	T3	Q19-Q21	3	2	1	1304	09º05´.5180"N	042º16´.9130"E	19	0.38	7.22	0	0	12	7	0	**RH**
				21	**14**	**7**	**1245.5**			**139**	**0.32**	**44.48**	0	0	**89**	**41**	**9**	**RH**
Erer ebada (Babiledistrict)	Horo roba	T1	Q1-Q3	3	2	1	1231.3	09º06´.1479"N	042º15´.6604"E	5	0.33	1.65	0	0	3	2	0	**RH**
	Qiltu gudal	T1	Q4-Q6	3	1	2	1228.3	09º05´.0337"N	042º15´.7436"E	2	0.33	0.66	0	0	0	2	0	**RH**
		T1	Q7	1	1	0	1224	09º03´.9900"N	042º16´.301"E	50	0.35	17.5	35	15	0	0	0	**RH**
	Horo roba	T2	Q8-Q11	4	4	0	1246.8	09º05´.8442"N	042º15´.3220"E	28	0.33	9.24	0	0	16	12	0	**RH**
	Qiltu gudal	T2	Q12-Q13	2	1	1	1239	09º04´.6500"N	042º15´.132"E	3	0.33	0.99	0	0	1	2	0	**RH**
	Kurfa gurati	T2	Q14	1	1	0	1231	09º03´.5800"N	042º16´.049"E	40	0.7	28	20	20	0	0	0	**RH**
	Horo roba	T3	Q15-Q18	4	4	0	1281.3	09º05´.2770"N	042º14´.956"E	10	0.3	3	0	0	6	4	0	**RH**
	Qiltu gudal	T3	Q19-Q21	3	3	0	1290	09º04´.9960"N	042º14´.978"E	6	0.28	1.68	0	0	3	3	0	**RH**
				21	**17**	**4**	**1246.5**			**144**	**0.37**	**62.72**	**55**	**35**	**29**	**25**	0	**RH**

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Gabdida (Mayu district)	Qaree barch	T1	Q1 to Q4	4	4	0	1408.3	08º42´.1864"N	041º56´.8300"E	20	0.58	11.6	0	0	10	10	0	**WL**
	Goro barch	T1	Q5	1	0	1	1395	08º42´.4104"N	041º56´.7313"E	0	0	0	0	0	0	0	0	**WL**
									Cont…									
	GolelGuba	T1	Q6	1	1	0	1398	08º42´.1770"N	041º56´.5380"E	1	0.3	0.3	0	0	0	1	0	**WL**
	Haro tajajib	T1	Q7	1	1	0	1425	08º43´.3078"N	041º56´.5159"E	5	0.3	1.5	0	0	2	3	0	**WL**
	Qare jajaba	T2	Q8 to Q15	7	6	1	1443.7	08º43´.3404"N	041º56´.4187"E	5	0.3	1.5	0	0	2	3	0	**WL**
	Goro dadacha	T3	Q16-Q21	7	7	0	1452.6	08º43´.1188"N	041º56´.1849"E	26	0.45	11.7	0	0	12	14	0	**WL**
				21	**19**	**2**	**1420.4**			**57**	**0.39**	**26.6**	0	0	**26**	**31**	0	**WL**
Alola (Mayudistrict)	kurfa midhugure	T1	Q1	1	0	1	1285	08º50´.2476"N	041º59´.4408"E	0	0	0	0	0	0	0	0	**WL**
	Hundake	T1	Q2	2	3	0	1300	08º50´.3083"N	041º59´.0202"E	3	0.2	0.6	0	0	0	3	0	**WL**
	Bakir	T1	Q3-Q7	4	4	0	1400.8	08º50´.4015"N	041º57´.8942"E	19	0.2	3.8	0	0	12	7	0	**WL**
	Okola	T2	Q8	1	1	0	1490	08º49´.8239"N	041º57´.1155"E	3	0.55	1.65	0	0	1	2	0	**WL**
	Bokot	T2	Q9	1	0	1	1421	08º49´.7185"N	041º57´.6634"E	0	0	0	0	0	0		0	**WL**
	Dugdahalo	T2	Q10	1	1	0	1373	08º49´.7249"N	041º58´.1522"E	2	0.2	0.4	0	0	0	2	0	**WL**
	Echiredildalo	T2	Q11	1	1	0	1347	08º49´.6930"N	041º58´.5758"E	3	0.2	0.6	0	0	2	1	0	**WL**
	Kurfa roqa	T2	Q12-Q14	3	1	0	1278	0849´.7696"N	041º59´.4045"E	5	0.7	3.5	0	0	2	3	0	**WL**
	Kurfa gurgure	T3	Q15	1	1	0	1454	37/X=0824454	UTM/Y=0976075	3	0.2	0.6	0	0	3	0	0	**WL**
	Arade	T3	Q16	1	1	0	1344	37/X=0824852	UTM/Y=0975510	3	0.2	0.6	0	0	2	1	0	**WL**
	Kurfa eda	T3	Q17	1	1	0	1397	37/X=0825381	UTM/Y=0975587	5	0.45	2.25	0	0	3	2	0	**WL**
	Warega	T3	Q18	1	1	0	1411	37/X=0826427	UTM/Y=0975940	2	0.2	0.4	0	0	2		0	**WL**
	Budot	T3	Q19	1	1	0	1358	37/X=0827044	UTM/Y=0976317	4	0.2	0.8	0	0	3	1	0	**WL**

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	Hare galma	T3	Q20	1	1	0	1324	37/X=0827415	UTM/Y=0976458	5	0.2	1	0	0	3	2	0	**WL**
	Badul	T3	Q21	1	1	0	1311	37/X=0827750	UTM/Y=0976581	4	0.2	0.8	0	0	3	1	0	**WL**
				21	**17**	**2**	**1366.5**			**61**	**0.28**	**17**	**0**	**0**	**36**	**25**	**0**	WL
Anani (Qare gobel) Fedis district	Qare gobel	T1	Q1-Q7	7	2	5	1360	08º56´.8160"N	042º01´.532"E	6	0.15	0.9	0	0	3	0	**3**	**BL**
	Wadaye qora	T2	Q8-Q10	3	0	3	1411	08º57´.08300"N	042º01´.973"E	0	0	0	0	0	0	0	0	**BL**
								Cont…										
	Sorata	T2	Q11-Q14	4	1	3	1381	08º56´.1711"N	042º02´.254"E	2	0.15	0.3	0	0	0	1	1	**BL**
	Wadaye mude	T3	Q15	1	0	1	1369	08º55´.6110"N	042º02´.753"E	0	0	0	0	0	0	0	0	**BL**
	Rasa wadaye	T3	Q1-Q21	6	2	4	1396	08º56´.693"N	042º02´.935"E	6	0.15	0.9	0	0	2	1	3	**BL**
				21	**5**	**16**	**1376.5**			**14**	**0.15**	**2.1**	0	0	**5**	**2**	**7**	**BL**
Anani (Kontomu) Fedis district	Kontom	T1	Q1-Q3	3	3	0	1463	08º59´.146"N	042º01´.913"E	25	0.2	5	0	0	13	12	0	**BL**
	Dinqo	T1	Q4	1	1	0	1452	08º59´.457"N	042º01´.883"E	3	0.25	0.75	0	0	2	1	0	**BL**
	Chore menzila	T1	Q5-Q6	2	2	0	1460	08º59´.635"N	042º01´.828"E	12	0.48	5.76	0	0	7	5	0	**BL**
	Onatune	T1	Q7	1	1	0	1459	09º00´.071"N	042º01´.805"E	2	0.25	0.5	0	0	2	0	0	**BL**
	Jima chore	T2	Q8	1	1	0	1508	09º00´.096"N	042º02´.380"E	7	0.2	1.4	0	0	4	3	0	**BL**
	Hurume	T2	Q9	1	1	0	1506	08º59´.883"N	042º02´.356"E	2	0.2	0.4	0	0	0	2	0	**BL**
	Bowa Abeyi	T2	Q10	1	1	0	1502	08º59´.690"N	042º02´.409"E	20	0.35	7	0	0	10	10	0	**BL**
	mukaracako	T2	Q11-Q14	4	3	1	1524	08º59´.259"N	042º02´.672"E	44	0.28	12.32	0	0	29	15	0	**BL**
	Jajaba nasisa	T3	Q15-Q16	2	2	0	1580	08º59´.165"N	042º03´.068"E	9	0.25	2.25	0	0	5	4	0	**BL**
	Gari halme	T3	Q17-Q18	2	2	0	1583	08º59´.273"N	042º03´.215"E	5	0.25	1.25	0	0	2	2	**1**	**BL**
	Ganda	T3	Q19-	2	1	1	1576	08º59´.372"N	042º03´.368"E	2	0.25	0.5	0	0	2	0	0	**BL**

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	tare tiqaa		Q20														
	Egdu	T3	Q21	1	1	0	1559	08º59´.509"N	042º03´.966"E	1	0.28	0.28	0	0	1	0	0	**BL**
				21	**19**	**2**	**1514.4**			**132**	**0.27**	**37.51**	0	0	**77**	**54**	**1**	**BL**
Bilusuma Midega tola district	Dugda dobe	T1	Q1	1	0	1	1342	08º48´.750"N	042º13´.633"E	0	0	0	0	0	0	0	0	**BL**
	Kurfa ilmanach a	T1	Q2	1	0	1	1301	08º48´.909"N	Y=042º13´.779"E	0	0	0	0	0	0	0	0	**BL**
	Dugda kuta	T1	Q3-Q6	4	4	0	1271	08º50´.086"N	042º14´.432"E	58	0.38	22.04	0	0	49	9	0	**BL**
	Dalu tiqoo	T1	Q7	1	0	1	1253	08º50´.290"N	042º14´.588"E	0	0	0	0	0	0	0	0	**BL**
									Cont…									
	Mudhi bali	T2	Q8-Q9	2	1	1	1298	08º50´.647"N	042º14´.540"E	2	0.35	0.7	0	0	2	0	0	**BL**
	Kurfa marsim	T2	Q10-Q12	3	2	1	1260	08º50´.184"N	042º13´991"E	15	0.2	3	0	12	3	0	0	**BL**
	Dugda kuta	T2	Q13	1	0	1	1308	08º49´.027"N	042º13´596"E	0	0	0	0	0	0	0	0	**BL**
	Koboyoh anis	T2	Q14	1	0	1	1379	08º48´.815"N	042º13.430"E	0	0	0	0	0	0	0	0	**BL**
	Godo bare	T3	Q15	1	1	0	1330	08º48´.855"N	042º13.730"E	5	0.33	1.65	0	5	0	0	0	**BL**
	Dugda dacha	T3	Q16	1	1	0	1340	08º48´.908"N	042º13.887"E	15	0.39	5.85	0	15	0	0	0	**BL**
	Dude gabab	T3	Q17	1	1	0	1280	08º49´.215"N	042º13.998"E	20	0.2	4	0	20	0	0	0	**BL**
	Laga dhiqaa	T3	Q18	1	1	0	1240	08º49´.312"N	042º14.453"E	20	0.8	16	0	20	0	0	0	**BL**
	Dugda gudaa	T3	Q19-Q21	3	2	1	1260	08º50´.080"N	042º14.433"E	45	0.75	33.75	0	45	0	0	0	**BL**
				21	**13**	**8**	**1294.9**			**180**	**0.42**	**86.99**	**0**	**117**	**54**	**9**	**0**	**BL**

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Note: Abbreviated symbols (T=Transect, Q=Quadrant, RH=Riverian Land Habitat, WL=Woodland Habitat, and BL=Bushland Habitat, A= Very fresh dungs, moist with odor dungs, B= Intact and fresh but dry without odor dungs, C= some of the boli get disintegrated dungs, D= all boli get disintegrated dungs to form amorphous flat mass and E= decayed dungs to stage not detected at a range of 2 m).

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Appendix-I: Table 2. Perpendicular distance (xi) measured from the center-line of the transect for each observed dropping in riverine, woodland, and bush land habitats of BES

Stratum 1/Riverine habitats/

Qs	T1	T2	T3	T4	T5	T6
Q1	0.05	3.55	4.55	0.05	4.05	5.05
Q2	0.55	3.05	4.05	0.55	0	4.55
Q3	1.05	2.55	3.55	0	3.05	4.05
Q4	0	2.05	3.05	0	2.55	3.55
Q5	0	1.55	2.55	2.05	2.05	3.05
Q6	0	1.05	2.05	0	1.55	2.55
Q7	0	0	0	3.05	1.05	2.05
Mean	**0.55**	**2.3**	**3.3**	**1.43**	**2.38**	**3.55**
T.d	**3**	**6**	**6**	**5**	**6**	**7**

Stratum 2/Woodland habitats/

Qs	T1	T2	T3	T1	T2	T3
Q1	0	4.5	5.5	0.5	1.5	5.5
Q2	0	0	5	0	0	5
Q3	1.5	3.5	4.5	1.5	2.5	4.5
Q4	2	3	4	2	3	4
Q5	2.5	0	3.5	2.5	0	3.5
Q6	3	2	3	3	4	3
Q7	3.5	1.5	2.5	3.5	4.5	2.5
Mean	**2.5**	**2.9**	**4**	**2.17**	**3.1**	**4**
T.d	**5**	**5**	**7**	**6**	**5**	**7**

Note: In the riverine habitat of stratum 1, transects from T1 to T3 and T4 to T6 were taken from Ebada Gamachu and Erer Ebada sites of Babile district respectively. In the woodland habitats (stratum 2), transects from T1 to T3 and T4 to T6 were taken from the Alola and Gabibda sites of Mayu Muluke district respectively

Qs = Quadrants

T= Transect

T.d.= Total number of droppings around each quadrant along a transect

• All measurements are in a kilometer

Stratum 3/Bushland habitats/

Qs	T1	T2	T3	T4	T5	T6	T7	T8	T9
Q1	0	0	0	0.5	4.5	2.5	0	4.5	0
Q2	0	0	0	1	4	3	0	0	3
Q3	0	0	0	1.5	3.5	3.5	0	3.5	3.5
Q4	0	0	0	2	3	4	2	3	4
Q5	0	0	0	2.5	2.5	0	2.5	0	4.5
Q6	3	0	5	3	2	0	3	0	5
Q7	3.5	1.5	5.5	3.5	1.5	5.5	0	0	5.5
Mean	**3.25**	**1.5**	**5.25**	**2**	**3**	**3.7**	**2.5**	**3.67**	**4.25**
T.d	**2**	**1**	**2**	**7**	**7**	**5**	**3**	**3**	**6**

Note: In the bushland habitats, transects from T1 to T3, T4 to T6, and T4 to T7 were taken from Anani (Qare Gobele), Anani (kontomu) sites of Fedis district, and Bilisuma site of Midega Tola district respectively.