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Population Estimates and Behavioral Ecology of Common Warthog (*Phacochoerus africanus* Gmelin, 1788) in Dabena Valley Forest, Western Ethiopia.

By

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This is to certify that the thesis prepared by Alemayehu Edossa, entitled "Population Estimates and Behavioral Ecology of Common Warthog (*Phacochoerus africanus* Gmelin, 1788) in Dabena Valley Forest, western Ethiopia" and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Zoology (Ecological and Systematic Zoology) fulfills with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Population Estimates and Behavioral Ecology of Common Warthog *(Phacochoerus africanus* Gmelin, 1788) in Dabena Valley Forest, western Ethiopia.

Alemayehu Edossa, PhD Thesis, Addis Ababa University, 2019

An ecological research on population estimate, behaviors and nutrient qualityof common warthog(*Phacochoerus africanus* Gmelin, 1788) was conducted in Dabena Valley Forest, Western Ethiopia from May 2016 to June 2018. This study was carried outin Gassi Controlled Area (GCHA) and Haro Aba Diko Controlled Hunting Area (HADCHA). Fixed half–width of strip line transect method was used for population estimation and enumeration. Population abundance and densities were analyzed using distance.Continual scan sampling method was used to assess actvitity budgets. Diet composition of was determined using feeding quadrat survey and microhistological analysis methods. Salt lick samples were dried in shade and analyzed by inductively coupled plasma spectroscopy. Seasonal variations of nutrient quality of common warthog were measured using clipped plant samples and fecal droppings. Dietary and fecal contents of C, N, P, neutral and acid detergent fiber were analyzed. Crude protein content was measured using Kjeldhal method. The total distance walked was 40.746 km in GCHA and 42.144 km in HADCHA during the wet and dry seasons. A total of 246 and 652 warthogs were counted in GCHA and HADCHA, respectively during the transect study. The two study areas were significantly different ($F_{1\,6} = 18.51$, $P < 0.05$) during the wet season and ($F_{1\,6} = 39.86$, $P < 0.05$) during the dry season in the number of common warthog population per transect. During the dry season, HADCHA possessed more mean of cluster density (5.18/km^2 (CV=7%) with a 95% CI of (5.9–4.44) than the GCHA (2.37/km^2 (CV=14%) with a 95% CI of (2.9–1.84). Warthogs were associated inthree vegetation zones along a transect line running from a grazing land into the *Combretum–Terminalia* woodland. Warthogs encounter rate was 1.97/km (CV=44%) and 1.75/km (CV=60%) in HADCHA *Combretum–Terminalia* habitat during wet and dry seasons, respectively. Adult common warthog individuals spent the highest proportion of the daytime in feeding (47.21%) followed by resting (14.29%) and walking (11.94%).From GCHA 41 and from HADCHA 45 forage species identified as annual dietary component of the animal from fecal samples. *Cyperus fischerianus, Digitaria abyssinica, Cynodon dactylon, Cynodon nlemfuensis, Hyparrhenia rufa* and*Andropogon abyssinicus*wereidentified as staple forage species of warthogs in both study areas.The mean sodium concentration in salt lick, common warthog ingested varied from 0.01 ±0.001Na meq/100g (Menjiko) to 0.08±0.006 meq/100g (Dodeta) during the dry season. However, the study areas were insignificantly different ($F_{1\,14} = 1.63$, $P > 0.05$). Warthogs foraged 1311 mg/100g and 1489.2 mg/100g dietrary phosphorous concentration, which was below the minimum threshold level leading to high risk of sterility and population decline in both study areas. Responses to crop raiding, habitat degradation and drought were also the major threats of common warthogs in the study areas. Hence, conservation of GCHA and HADCHA should get the acceptance of the local residents. Wildlife laws should be introduced and practiced in the study areas.

Key words/phrases: Behaviors, common warthog, Dabena Valley Forest, ecology, estimates population

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ACRONYMS

ADF	Acid Detergent Fiber
AF	Adult Female
AD	Adult Male
DVF	Dabena Valley Forest
DCP	Dietary Crude Protein
FCP	Fecal Crude Protein
GCHA	Gassi Controlled Hunting Area
HADCHA	Haro Aba Diko Controlled Hunting Area
IBC	Institute of Biodiversity Conservation
MDP	Mean Detection Probability
MER	Mean Encounter Rate
MECS	Mean Expected Cluster Size
MOCS	Mean Observed Cluster Size
NDF	Neutral Detergent Fiber
RFO	Relative Frequency Occurrence
SAF	Sub–Adult Female
SAM	Sub–Adult Male
UJS	Unidentified Juvenile Sex

1. INTRODUCTION

Our biological world is dynamic, regulated by ecological and evolutionary processes (Geldmann, 2013). There are 4629 extant mammalian species on earth.They reveal variation in ecological adaptation and behaviors (Boddicker *et al.,* 2002). Mammals are extremely important for the functioning of global ecosystems (Gutbrodt, 2006; Young *et al.,* 2013). Savanna supports diverse assemblages of wild herbivores (Pringle *et al.,* 2010; van der Waal, 2010; Keesing and Young, 2014) and comprises important resource components for fast growing human population (Cech, 2008; van der Waal, 2010). Hence, the most speculated key determinants of savanna ecosystems are herbivores, fire and the availability of resources (water and nutrients) (Roininen *et al.,*2007; Bowman and Murphy, 2010).

Suidae are one of the most widespread terrestrialmammals (David, 2013).They are one of the non–ruminant super family even–toed (Cetartiodactyla) ungulates of the Order Artiodactyla(De Jong*et al.,* 2016; Frantz*et al.,* 2016).Theypossess high crowned, bunodont and many teeth, with stomach less complex than the ruminants (Groves and Grubb, 1933; Walther, 1974). Under Family Suidae,there are two genotypically, phenotypically and morphologically different warthog species. These are common warthog (*Phacochoerus africanus*Gmelin, 1788)and desert warthog(*Phacochoerus aethiopicus*)(Grubb, 1993: Yalden*et al.,* 1996; Butynski and de Jong, 2009). The common warthogs constitute four known subspecies based on their skull morphology (Grubb, 1993; d'Huart and Grubb, 2001; Muwanika *et al.,* 2003). They commonly occur in shrublands and grassy plains at altitudes of up to 3000 m asl (Mason, 1982; Thorp, 2012). They

also exist in *Combretum–Terminalia* woodland ecosystem, open grassland, riparian forests (White, 2010; Thorp, 2012; Pinto, 2013) and survive in harsh arid environments (d'Huart and Grubb, 2001). Desert warthogspossess two subspecies (d'Huart and Grubb, 2001) that live on grassland steppes on altitudes up to 500masl and arid environments (Mason, 1982; Thorp, 2012). The two warthog species diverge significantly in the specific niches they acquire (Kingston and Harrison, 2007).

Common warthogs are social animals (Hjertlöv, 2015). Females of common warthogs expend most of their life in groups called sounder and adult males are usually solitary and join female groups for mating (White, 2010). Common warthogs are primarily grazers (White, 2010; Hjertlöv, 2015).They also feed on roots, berries, bark of young trees (Treydte *et al*., 2006; Kahana *et al*., 2013) and occasionally on carrion (Lameed and Adetola, 2012).They use their snouts and tusks to excavate rhizomes and bulbs (Clauss *et al.,* 2008), and dig up licking materials (Lameed and Adetola, 2012). They are effective in fiber digestion (Clauss *et al*., 2008). Common warthogs show cooperative breeding (Cumming, 1975; White and Cameron, 2008), andthey are characterised by high fecundity (Hoffman and Sales, 2007).Warthogs exhibit social interactions through body rubbing and grooming (Svemer, 2010). They exhibit exciting varieties of nutritional niches, behaviors, and forms (Clauss *et al*., 2008).

Humans have a profound impact on the earth, which is unparalleled by any other single species.This leads our planet earth to enter a new geological era (Madden, 2008; Ogutu *et al.,* 2008; Geldmann, 2013). Consequently, in many parts of Africa warthogs are killed for bushmeat.They are also consideredas crop pests(Cumming, 2005;Hjertlöv, 2015).Nevertheless,

common warthogs have enormous ecological functions (Sanderson, 2012). When they root in the ground, they help soil to aerate, encouraging plant growth (Kahana*et al.*, 2013; Hjertlöv, 2015). Geographical variation and specific taxonomy characteristics of the common warthog are poorly understood (Grubb, 1993). Population status, ecology, behavior, genetic diversity and conservation status of most species of wild Suidae are important in order to identify their taxonomic features (Groves and Grubb, 1933). Despite common warthogs are ecologically important and wiedly distributed across their range, only little work has been done pertaining to theirecology and conservation.

Hence, the main purpose of this study was to investigate population estimates and behavioral ecology of common warthog in Dabena Valley Forest (Gassi controlled hunting area (GCHA) and Haro Aba Diko contolled hunting area (HADCHA), Buno Bedelle Zone,western Ethiopia.

2. REVIEW OF LITERATURE

2.1. Population abundance of common warthog

Suidae are the most successful mammals (Ermias Deribe, 2001; Gui–sheng *et al*., 2006). Members of the family Suidae have diverged over extended evolutionary periods in various environments and have a widespread distribution (Darfour–Oduro *et al.,* 2015). They were put together with Hippopotamidae for decades until molecular analyses demonstrated that both are members of distinct families (Randi *et al.,* 1996; David, 2013; Frantz *et al.,* 2016). Suidae have three recognized subfamilies from the extant species: Phacochoerinae (*Phacochoerus*), Babyrousinae (*Babyrousa*) and Suinae (including genus *Sus*, *Potamochoerus* and *Hylochoerus*) (Fowler, 1996; Gui–sheng *et al*., 2006).Taxonomic relationships within Suidae have typically been assessed based on morphological characters and molecular studies focusing on nuclear and mitochondrial genes (Frantz *et al.,* 2016). However, their taxa and phylogeny were not adequately studied and the phylogenetic relationships among subfamilies of Suidae, genus, species groups and species are not clearly stated (Gui–sheng *et al*., 2006;David, 2013).

Suidae are social animals.There are17 classified pig species including warthogs (Somers *et al.,* 1995; Thorp, 2012). There are two phenotypically and morphologically separate warthog species (Grubb, 1993; Yalden *et al.,* 1996; Butynski and de Jong, 2009). These are the common warthog(*Phacochoerus africanus*) and the desert warthog or Cape warthog (*Phacochoerus aethiopicus*) (Mason, 1982; Svemer, 2010; Thorp, 2012; David,2013). The two species of warthogs at first called *Sus aethiopicus* and *Sus africanus* recognized universally for 130 years following Pallas and Gmelin (Grubb and d'Huart, 2010). Mitochondrial DNA investigation has

recently confirmed that the common and desert warthogs are two genetically distinct and widely divergent species, with a divergence time estimated at 4.5 million years ago (d'Huart and Grubb, 2001; Butynski and de Jong, 2009). Warthogs are a unique group of wild pigs because of their peculiar cheek teeth and bearing wart (Grubb and d'Huart, 2010; De Jong *et al.*, 2018). The canines in the genera have evolved to be among the largest of any mammals, relative to body size (Groves and Grubb, 1993). The geographic ranges of the two species of warthogs overlap at least narrowly in northern Somalia, northern and eastern Kenya and southern and south–eastern Ethiopia, but there is no sign of hybridization (d'Huart and Grubb, 2001; Butynski and de Jong, 2009). Nevertheless, Grubb and d'Huart (2010) recognized the geographic range of warthogs' species to be very distinct.

The common warthog(Fig.1) is widely distributed throughout the African countries (Fig.2) (Mason, 1982; d'Huart, 1997; Thorp, 2012; Hjertlöv, 2015). It has a large range, extending across much of sub–Saharan countries, with scattered populations occurring from the Sudan in the east to Senegal. Its range also extend from Guinea savannah in West Africa, Central Africa, and Ethiopia to south and the northern parts of the Republic of South Africa (d'Huart and Grubb, 2001; Hoffman and Sales, 2007; Swanepoel*et al.*, 2016).

Figure1. An adult male common warthog in HADCHA (Camera trap: Habte J. Debella, 2018).

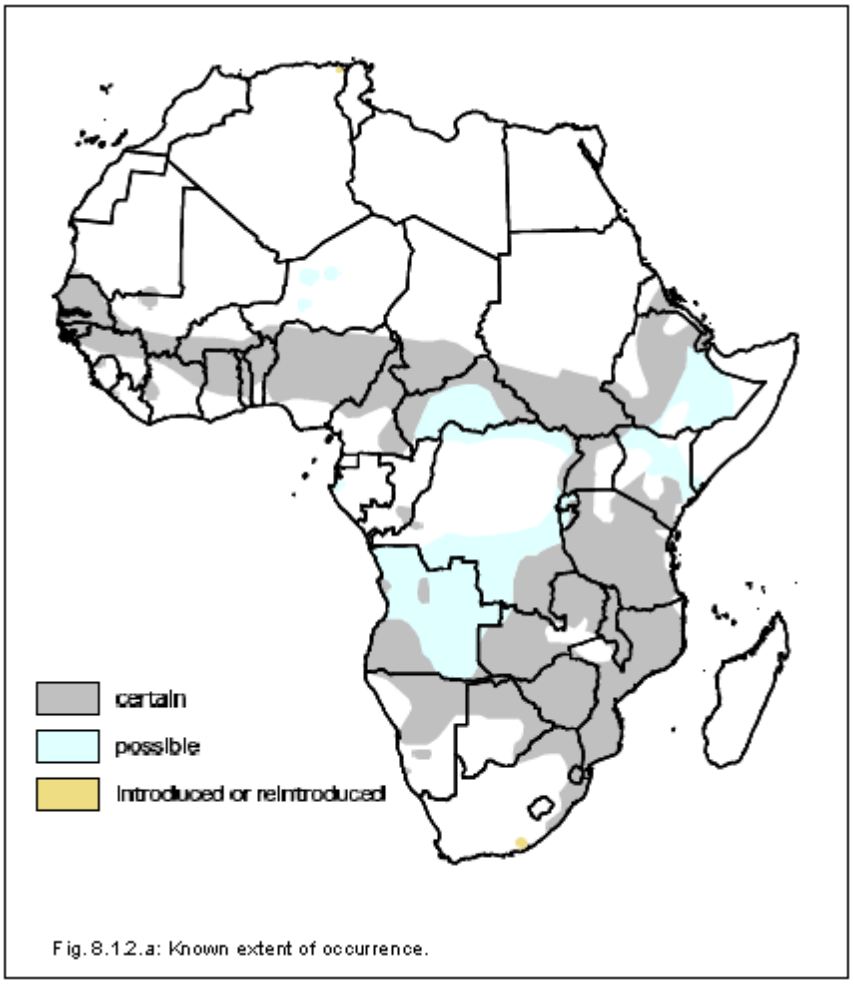


Figure2. Distribution of common warthogpopulation in Africa (Source: d'Huart, 1997).

Based on skull morphology, common warthog has four recognized sub–species,which are distributed throughout most African countries(d'Huart and Grubb, 2001; Muwanika *et al.,* 2003; De Jong *et al.,* 2016). These are, Nolan warthog (*Phacochoerus africanus africanus* Gmelin, 1788)(Fig. 3) which inhabits in Ethiopia, Burkina Faso, Ivory Coast, Democratic Republic of the Congo, Ghana, Guinea–Bissau, Chad, Mauritania, Nigeria, Senegal, and Sudan (Grubb, 1993; d'Huart and Grubb, 2001; De Jong *et al.,* 2016) and its status category is widely distributed and abundant (Oliver, 1995). The Eritrean warthog (*P. a. aeliani* Cretzschmar, 1828) (Fig. 4) which occurs in northern Ethiopia, Eritrea, Djibouti and Somalia (Grubb, 1993; d'Huart and Grubb,

2001; Muwanika *et al.,* 2003) and seriously threatened or endangered (Oliver, 1995). The Central African warthog (*P. a. massaicus* Lönnberg, 1908) (Fig. 5), which occurs in Kenya, Tanzania, Zaire, Rwanda, Burundi, Zambia, Malawi, and Angola (Grubb, 1993; d'Huart and Grubb, 2001; De Jong *et al.,* 2016) and widespread and abundant (Oliver, 1995). The Southern warthog (*P. a. sundevallii* Lönnberg, 1908) (Fig. 6), which occupies in Namibia, South Africa, Zimbabwe and Botswana (Grubb, 1993; d'Huart and Grubb, 2001) and widespread at low density (Oliver, 1995). Therefore, Ethiopia has two sub–species of common warthog population: Nolan warthog and the Eritrean warthog (Muwanika *et al.*, 2003).

Figure 3. Nolan warthog (*Phacochoerus africanus africanus*) (Source: Association of Zoos and Aquariums (AZA), 2008)

Figure 4. The Eritrean warthog (*P. a. aeliani*) (Source: Muwanika *et al.*, 2003).

Figure 5. The Central African warthog **(***Phacochoerus africanus massaicus*) (Source: Thorp, 2012).

Figure 6.The southern warthog (*P. a. sundevallii*)(Source: AZA, 2008).

Common warthogs are communal animals with a flexible social structure (Hjertlöv, 2015). They live in relative groups called sounders, consisting of one or more females with one or more successive litters (Fig. 7) (Svemer, 2010). Males usually depart their natal groups before the age of two years. Both sexes reveal a high degree of philopatry (Vercammen and Mason, 1993; Svemer, 2010; White, 2010). Warthogs exist in clans, which comprise some groups of sounders whose home ranges overlap significantly with other sounders owing to the same clan (Svemer, 2010; White, 2010).

Figure 7. Common warthogsin sounder in HADCHA (Camera trap:Alemayehu Edossa, 2017).

Common warthog group formation depends on sex, age and season of the year (White, 2010). Adult males seldom form sunders (White, 2010; Hjertlöv, 2015). Closely related philopatric females usually form sounder (Keuling, 2009;Swanepoel*et al.*, 2016). Grouping behavior in adult females is more complex, and two obvious reproductive strategies are practiced (White, 2010). These constitute adult females that raise their young alone and that raise their young in sounders with other individuals. Hence, unidentified juvenile sex common warthogs are rarely seen alone (White, 2010; Hjertlöv, 2015). The tendency of sounder formation is limited by

resource competition. Predation possibly influences sounder structure (Vercammen and Mason, 1993; White, 2010). Seasonal variation may influence group formation within and among ungulate species (Keuling, 2009; Walter *et al.,* 2013). Hence, common warthog grouping behavior changes as a function of season and become fragmented during the dry season because of competition for resources (Svemer, 2010; White, 2010). Seasonal changes in–sounder size and their composition also depend on reproductive patterns and separation for parturition of females (Keuling, 2009; Swanepoel *et al.,* 2016). Therefore, sounder formation benefits individuals common warthog through predator detection through increased vigilance and dilution effects (Durand*et al.,* 2007; White, 2010). It also helps to locate food resources (White, 2010).

Common warthog population is characterised by high fecundity (Hoffman and Sales, 2007; Swanepoel*et al.,* 2016) and has a mean of 4–5 piglets per litter and a gestation period of 167 to 175 days, which is long, compared with other pig species. Females usually become fertile within 4–5 months after the rainy season and give birth during the dry season (Vercammen and Mason, 1993; Hoffman and Sales, 2007).

2.2. Habitat association of common warthog

Animals exhibit specific habitat distribution all over the globe. Habitat selection influences the abundance and distribution of species and affects the spread of large mammals across the landscape (Stewart *et al.,* 2002; van Beest *et al.,* 2014). Some animals are cosmopolitan in having worldwide distribution but most animals have restricted habitat because of some kind of barrier (Verma and Agarwal, 2004). The survival and adaptation of organisms in a particular habitat is influenced by different factors (Cox and Moore, 2005; Andrews and Hixson, 2014).

These factors can be responsible for the inability of a species to survive in a particular place, unless the species is able to respond through physical or behavioral change (Brown and Lomolino, 1998; Cox and Moore, 2005). Species, physiology also determine their existence in limited range of environmental conditions (Hillebrand*et al.*, 2009). Therefore, species rely on their own evolutionary past history and origin of dispersal (Cox and Moore, 1993 and 2005). Habitat change also influences the allocation and abundance of wildlife and levels of biodiversity loss are usually linked with a reduction in the extent of original habitat (Desbiez *et al.*, 2009).

Plant composition and structure of certain habitats easily attract ungulates (Kahana *et al.*, 2013). The distribution and abundance of ungulate populations are affected by accessibility of food and cover, because these resources supply the vital biological and physiological necessities for ungulates (Sanchez–Rojas and Gallina, 2000; Stewart *et al.*, 2002; Hillebrand*et al.*, 2009). Consequently, ungulate's foraging behavior of optimal resource, can serve as an index of habitat quality and more sensitive indicator of population status (Perrin and Brereton–Stiles, 1999; Kahana *et al*., 2013). Hence, animal's climax choice of habitat is affected by its interspecific competition between species, which exploit very similar sets of resources (Barker, 2005; Thorp, 2012). Hence, differential habitat selection restricts dietary overlap and competition between species of similar diets (Cain III *et al.*, 2017).Mobæk *et al.*, (2009) and Brandtberg and Dabelsteen, (2013) distinguished that habitat used by large herbivores results from different processes operating at multiple spatial scales from landscape to diet choice.

The success of animals in a particular habitat type is impacted by annual variation in availability of water and seasonal cycles (Vinod and Sathyakumar, 1999; Sanchez–Rojas and Gallina, 2000;

Kahana *et al*., 2013). These stochastic effects can determine where animals live and adapt to the existing conditions (Andrews and Hixson, 2014; Eennitt *et al.,* 2014). Traill and Bigalke (2006) described that herbivore distribution in certain habitat is primarily determined by distance to surface water. Predators affect animals to modify their habitat preferences and movement patterns to reduce their likelihood of being encountered or captured (Sanchez–Rojas and Gallina, 2000; Fischhoff *et al*., 2007; Thorp, 2012). On the other hand, highly suitable habitats should have a proportionally higher number of presence records (Paudel *et al.,* 2015).

Human activity has an impact on the habitat choice of common warthogs.They are vigilant animals with a movement distance larger than most other animals (Thorp, 2012). Common warthogs prefer and are well distributed throughout *Combretum–Terminalia* woodland or broad–leaved deciduous woodland ecosystem (Kingdon, 1997; Sponheimer and Lee–Thorp, 2001; White, 2010; De Jong *et al.,* 2016). High warthog densities in savanna are associated with the availability of deserted aardvark holes, which they use to escape from fluctuating nighttime temperatures and predators (Kingdon, 1997; Cilliers, 2002). Riparian forest habitats also harbor common warthogs, as they are the source of waterholes (Fig. 8).

Figure 8. Common warthogs grazing in ariparian habitatin HADCHA (Photo: Alemayehu Edossa, April 2017).

Common warthogs and many other ungulates forage in open grassland habitat (Fig. 9) (Thorp, 2012; Kahana *et al*., 2013; De Jong *et al.,* 2016). High degree of spatial heterogeneity of glades in the soil and plant composition significantly influences the distribution and abundance of wild herbivores (Augustine, 2004; Anderson *et al.,* 2016). Glades in the *Combretum–Terminalia* woodland matrix have unique plant communities, which influence the pattern of resource used by animals (Kahana *et al*., 2013; Swanepoel*et al.,* 2016). Glades mainly serve as feeding sites for several species of ungulates due to plenty of grasses and herbs in relatively small areas (Augustine, 2004; Kahana *et al.,* 2013). Common warthogs seeking this habitat for rich nutrient occur in *Brachiara*spp, *Cyodon* spp, *Panicum* spp and others (Augustine, 2004; Thorp, 2012;

Kahana *et al.,* 2013). This generates a positive feedback circle where feces of warthogs and other animals forage in this habitat, adding nourishment on the ground (Thorp, 2012). Glades edges also provide as shelter for common warthogs andother ungulates against predators (Augustine, 2004; Kahana *et al*., 2013).

Figure 9. Common warthogs grazing in the open grassland habitat(Photo: Alemayehu Edossa, April 2017).

2.3. Activity pattern of common warthogs

Activity pattern is a significant biological element of any animal species (Espinosa and Salvador, 2017; Kasiringua *et al.,* 2017) and it is commonly described how animals regularly allocate time for specific activities (Mahenya, 2016). Daily activity pattern reflectsboth physiological

characteristics and ecological interactions (Espinosa and Salvador, 2017; Leuchtenberger *et al.,* 2018). Animals' time budget consists of several important activities, such as foraging, resting, moving, vigilance and others (Mahenya, 2016; Rogers, 2016; Kasiringua *et al.,* 2017).The activity rhythm of most mammal species is synchronized by endogenous biogeochemical processes and typically stimulated by cyclical environmental variations, such as photoperiod (Kasiringua *et al.,* 2017; Leuchtenberger *et al.,* 2018). Photoperiod in turn affects hormone levels, thermoregulation and water turnover, reproduction, metabolic levels and foraging time (Hill *et al.,* 2003). Hence, mammals usually regulate their daily activity pattern according to the light–dark cycle and specialize in a particular period (Owen–Smith, 1998; Ogutu *et al.,* 2012; Leuchtenberger *et al.,* 2018).

Day lengthis an important reflection of seasonal behavior patterns of mammals, which enables them to determine the period within which obligate diurnal or nocturnal rhythmto conduct their essential activities (Hill *et al.,* 2003). Seasonal disparities in day length lead ecological limitation of behavior, because short wet days restrict the length of the time available for life activitiesof diurnal species. Long dry days and short nights are also potential constraints for nocturnal species and restrictthe length of the active period (Owen–Smith, 1994; Hill *et al.,* 2003; Jian–bin *et al.,* 2006). Mammal species sharetheirdaily budget time to various activities;reflect significant cohesion between ecology and behavior (Hill *et al.,* 2003; Vallance, 2015).Whenever mammals are unable to perform two activities simultaneously they will be obligated to schedule certain behaviors preferentially and reduce opportunities to engage in other biologically important activities (Hill *et al.,* 2003;Jian–bin *et al.,* 2006; Vallance, 2015; Rogers, 2016).

During the morning and afternoon hours whenweather conditions are neither too cold nor too hot, food needs should be the primary consideration of most mammals (Rodriguesand Monteiro–Filho, 2000; Owen–Smith and Traill, 2017). During the midday hours when conditions are hot, animals might need to move into shaded sitesfor resting (Owen–Smith, 1998; Kasiringua *et al.*, 2017; Owen–Smith and Traill, 2017). However, there is variation in activity patterns of time budget among mammalian populations (Leuchtenberger *et al.*, 2018). Hence, common warthogs are active during the day and they sleep in holes usually neglected by other animals during the night, which is unusual in other ungulates (Treydte *et al*., 2006; Hjertlöv, 2015).

Common warthogs scan their environment when they recognize predators andthere is difference in forage quality between habitats (Fowler, 1996; Hjertlöv, 2015). Warthogs scan is least in abundant grass (Arenz and Leger, 1999). Olfaction togather with vocalization and hearing, are used by common warthogs to communicate (Fowler, 1996; Hjertlöv, 2015).Family groups communicate each other with different sounds like squeaks, growls, chirps, and grunts. When a common warthog is alarmed, it runs with tail upright as an alarm for conspecifics (Fowler, 1996). Common warthogs love to roll in mud (Fowler, 1996). The mud covers their hairless skin; it helps keep them cool and protects them from biting flies and other insects (Treydte *et al*., 2006; Clauss *et al*., 2008).

2.4. Feeding ecology of common warthog

2.4.1. Diet composition

Feeding ecology includes the relationships that exist among food accessibility, feeding activity, diet choice, and the effects of variation in the quality and quantity of food on feeding behavior of animals (Bailey *et al.,* 1996; Paul, 1998; Katona and Altbäcker, 2002). As forage density and

biomass shrink, larger mammals adjust their feeding behavior by increasing bite volume and limit their specialization on plant species and parts (Gutbrodt, 2006). The increase in bite size supports mammals to maintain constant rate of ingesting fodder regardless of the quality of plant parts. When the cut volume and bite rates change, the time allocated to foraging and home range size increase as the availability of biomass shrinks (Paul, 1998; Gutbrodt, 2006). Empirical studies point out that large herbivores have accurate spatial memories and have the ability to retain information to improve foraging activity (Wiggins *et al.,* 2006).With such skills, large herbivores could revisit nutrient rich sites more frequently than to nutrient poor sites (Bailey *et al.,* 1996; Moser *et al.,* 2006).

Suidae are distinct among artiodactyls in their digestive physiology (Somers *et al.*, 1995; Thorp, 2012). Thecommon warthog is a hindgut fermenter with significant microbial fermentation and protozoan population in parts of the digestive tract (Booyse and Dehority, 2012). They spend most of their time foraging, and they are specialized grazers and depend on high quality food (Treydte *et al*., 2006; Clauss *et al*., 2008; Mgqatsa, 2010). During the foraging period, some plant species are ignored whereas several others forage speciesare accepted (Macandza *et al.,* 2004). Accepted pieces are categorized as staple and preferred food items (Petrides, 1975). Staple food species are foodspecies that are eaten in large quantities whereas a preferred food species is a species that is found in a greater quantity in the diet compared to its proportion in the environment (Venter, 2006; Strauss, 2015). Common warthogs select certain grass species in greater quantities than other mammalian species and show a potential to deleterious impact on grazing resources (Clauss *et al*., 2008; Mgqatsa *et al.,* 2010).

During the dry seasons, they prefer to stay close to cattle enclosure (Fig.10) in order to acquire nutrient rich grasses (Treydte *et al*., 2006). The front knees are padded, kneel on their front knees and graze (Hjertlöv, 2015). The nutrient content of grass depends on rainfall and on the availability of macro and micro–nutrients in the soil. Similar nutrient enrichment can be observed in areas receiving high inputs of excreta from domestic livestock (Leus, 1994; Treydte *et al.,* 2006).

Figure 10. Common warthogs and cattle foraging in the study area(Photo: Alemayehu Edossa, April 2017).

During the dry season, warthog's diet is restricted to a few plant species compared to the wet season (Treydte, 2004). During the wet season, warthogs graze different species ofannual grasses

and perennial plant materials (Plate 1) whereas during the dry seasons, they consume on bulbs, berries, bark of young trees, rhizomes, and nutritious roots (Sponheimer and Lee–Thorp, 2001; Thorp, 2012). Common warthogs and other Suidae have a distinctive adaptation to use their snout for rooting (David, 2013; Kahana *et al.*, 2013; Hjertlöv, 2015),which are not used by other ungulates (Made *et al.*, 2013). They use their snouts and tusks to excavate rhizomes and bulbs. Rhizomes and bulbs may also provide water for the animal during periods of drought (Sponheimer and Lee–Thorp, 2001; Treydte, 2004; Treydte *et al*., 2006). These allow the common warthogs to survive in a wider range of environments during harsh seasons (Vercammen and Mason, 1993; Made *et al*., 2013). The wide distribution of common warthog in the African savanna ecosystems is due to their dietary flexibility (Kahana *et al.*, 2013). They forage sedges, fallen fruits, certain forbs and animal foods. Common warthogs eat their own dung and the dung of African buffalos, rhinoceroses, waterbucks, and francolins (Sponheimer and Lee–Thorp, 2001; Thorp, 2012). Warthogs consume small vertebrates, invertebrates, eggs and kill gazelle fawns to include animal protein in their diet (Roberts, 2012 and 2014).Warthogs and other suids are also known to consume carrion, and other large vertebrate matters in their diets as scavenger (Lameed and Adetola, 2012).

2.4.2.Salt licking

Soil nutrients of the ecosystem vary extensively in space and time (Augustine, 2004). Black cotton soils (pellic vertis*)* and red sand soils (ferric and chromic luvisols) are thetwo broadly defined soil types in the savanna ecosystem. These are widespread throughout in the East African countries (Omphile and Powell, 2002; Succow and Mundt, 2013; Young *et al.*, 2013). Soil nutrients influence the strength and direction of effects of wild herbivores on plant species richness and physical structure (Lehmann *et al.*, 2011; Young *et al.*, 2013). Hence, in ecosystems

with highly seasonal precipitation, soil moisture availability may be the key limiting resource for plant growth (Holdo and Mack, 2014). The accessibility of soil nutrients is a strong regulator where large herbivores concentrate their impact on savanna vegetation (van der Waal, 2010). Simultaneously, herbivores can exert either positive or negative effects on tropical savanna soil (Bakker *et al.,* 2009; Holdo and Mack, 2014; Risch *et al.*, 2015).

Herbivores usually return mineralized nitrogen and organic carbon through waste products coupled with rapid breakdown of litter (Metcalfe*et al.,* 2014; Risch *et al.*, 2015). These speed up nitrogen mineralization rates and cycling of carbon (Hobbs, 1996; Ritchie *et al.,* 1998; van der Waal, 2010). Thus, herbivores are responsible to increase soil nitrogen and carbon and regulate organic carbon and plant nitrogen concentration through the direct effect of nutrient excretion (Hobbs, 1996; Bakker *et al.,* 2009; Haynes *et al.,* 2014). In savanna ecosystems,soil formation by termites also improves carbon, nitrogen, and phosphorous configuration, which are of primary importance for fruit production near mounds (Brody *et al.*, 2010).

Salt licks are mineral–rich places (Matsubayashi *et al.,* 2006; Hon and Shibata, 2013) that occur naturally in certain locations in the ground surface of forest and savanna ecosystems (Lameed and Adetola, 2012; Slabach *et al.,* 2015). Panichev *et al.,* (2017) noted that the occurrences of salt lick sites are probably due to biogeochemical processes. Salt licks are a static resource (Jokinen *et al.,* 2016) where omnivores, carnivores, herbivores frugivores and insectivores are actively and frequently visit and ingest soil (Klaus *et al.,* 1998; Ayotte *et al*., 2006; Hon and Shibata, 2013). Ungulates are frequent around salt lick sites (Hon and Shibata, 2013; Jokinen *et al.,* 2016; Panichev *et al.,* 2017). Salt licks contain high levels of essential minerals such as nitrogen, phosphorus, sodium, potassium, calcium and magnesium (Matsubayashi *et al.,* 2006; Lameed

and Adetola, 2012; Hon and Shibata, 2013; Chew *et al.*, 2014). These essential minerals are lacking in thediets of animals (Hon and Shibata, 2013). Shortage of macro and micro elements are not necessarily result of inadequate dietary ingestion only, but rather of digestive disorders linked with spring forage alteration (Ayotte *et al*., 2006). Hence, mammals of tropical savanna are obligated to supplement minerals from other sources to ensure enough nutritents in their diets (Matsubayashi *et al.,* 2006; Ping *et al.*, 2011; Lameed and Adetola, 2012).

Common warthogs salt lick mostly in the morning and afternoon hours (Lameed and Adetola, 2012). The greatest peaks in visits of such sites occur from December to February (Ayotte *et al*., 2006; Hon and Shibata, 2013; Panichev *et al.,* 2017).The peak periods visit lick site coincide with plant phenology (variable timing of plant growth and forage preferences) (Poole *et al.,* 2010; Jokinen *et al.,* 2016). The visitation periods associated with the increased physiological demands of growth, or weight regain, motivated by electrolyte loss related to stress of sudden changes in forage chemistry of the animal (Ayotte *et al*., 2006; Ping *et al.*, 2011; Hon and Shibata, 2013). Common warthogs use wet (Fig. 11) and dry licks (Fig. 12) (Ayotte *et al*., 2006; Ping *et al.,* 2011; Jokinen *et al.,* 2016). Wet lick is linked with the change in forage chemistry and the loss of sodium from sweat or urine is much more than other times of the year (Ping *et al.,* 2011) and underground water springs (Ayotte *et al*., 2006). Dry licks usually occur along streams or riverbed sbecause unweathered soluble elements are deposits above less firm layers, and become exposed by erosion as dry licks (Ayotte *et al*., 2006).

Figure 11. Common warthog drinking lick materials in the study area (Camera trap: Habta J. Debella, March 2018)

Figure 12. Common warthogs eating lick materialsinHADCHA (Photo: Alemayehu Edossa April, 2018).

2.5. Nutrient quality

The proportion and numberof plant species incorporated in the diet indicate the breadth of an animal's food niche and represent diet quantity (Gutbrodt, 2006; Butt and Turner, 2012). Diet content of nitrogen, carbon, phosphorous, crude protein, fiber content (neutral detergent fiber (NDF) and acid detergent fiber (ADF) indicate diet quality (Clauss *et al*., and Codron *et al.*,2007). Non–ruminant ungulates are more efficient in processing low quality food (high fiber content) than ruminants (Kartzinel *et al.,* 2015). They compensate a less nutrient extraction of low quality foods by foraging more such food items (Codron *et al.,* 2007; Cromsigt *et al.,* 2009; Codron*et al.,* 2016). Due to this extent of food quality tolerance, non–ruminant ungulates use a wider variety of habitats than ruminants (Cromsigt *et al.,* 2009; Kahana *et al*., 2013). On the other hand, ungulates directly speed up nutrient turnover for uptake by microbes and plants by excreting nutrients in the form of readily available (Metcalfe *et al.,* 2014). Furthermore, they can influence nutrient yield by modifying the quality and quantity of plant debris available for decomposition indirectly (Hobbs, 1996; Metcalfe *et al.,* 2014). Therefore, nutritional status of plants and plant eating animals is essential for wildlife population and their habitat management (Treydte *et al.,* 2006).

Common warthogs show particular adaptation of high crowned teeth to its special dietary niche and long ingesting retention times (Clauss *et al*., 2007 and 2008). Hence, they are particularly efficient in fiber digestion like grazing ruminants. Thus, to obtain a nutritionally adequate diet and high mineral concentrations, they tend to forage on a variety of plant species (Dearing *et al.,* 2000; Mphinyane *et al.,* 2015). On the other hand,intake of N, P and C ofcommon warthogs can be maximized to a far greater degree by foraging grasses in neglected glades than relative to

surrounding plant communities (Augustine, 2004). A plant species, which is low in nitrogen may be high in digestible energy, whereas another species, may be high in sodium, but low in digestible energy (Lyons *et al.,* 1999; Dearing *et al.,* 2000). Foraging high protein and low fiber content not only optimize energy and nutrient intake, but also minimize retention time, thus increasing intake capacity (Zweifel –Schielly *et al.,* 2012).

2.6. Threat and status of common warthogs

Human and wildlife are fundamental components of many ecosystems. They live in harmony unless their interests come to conflicts and their activities start to deconstruct each other (Shemwetta and Kideghesho, 2000; Parry and Peres, 2015; Olsson *et al.,* 2017). Wildlife near human habitat decreased substantially in the recent past (Rogala*et al.,* 2011; Olsson *et al.,* 2017). The conflict between human and wildlife ranks among the main threats to biodiversity conservation, and has become frequent and severe in different parts of Africa (Pullin, 2002; Mulonga *et al.,* 2003; Madden, 2008). Crop raiding is a cause of major conflict between farmers and wildlife throughout the world (Mulonga *et al.,* 2003; Leta Gobosho Amaja *et al.,* 2016). Crop damage and other forms of human wildlife–conflict also vigor illegal hunting, but on a smaller scale than hunting for bushmeat (Naughton–Treves *et al*., 2003; Olupot *et al.,* 2009; Gandiwa, 2011). The conflict becomes more widespread as development expands, human population increases, and global climate changes and other human and environmental factors put human and wildlife in greater direct competition due to shrinking of resources (Mulonga *et al*., 2003; Madden, 2004; Leta Gobosho Amaja *et al.,* 2016).

Common warthogs have high ecosystem role (Sanderson, 2012). They are known as pioneer species and are one of the first species, which inhabit and make use of formerly disturbed

habitats.These animals have potentially accelerating nutrient turnover in soils and grasses supporting their restoration (Treydte *et al.* 2006; Swanepoel*et al*., 2016). When warthogs root in the ground, it aids to churn up soil and helps the soil to aerate which aids plant growth (Kahana *et al.,* 2013; Hjertlöv, 2015). Common warthog holes also have significant ecological roles in sheltering lions. Common warthogs have economicbenefits and serve as trophy hunting, eco–tourism and used for subsistence meat production by local community (Swanepoel *et al.,* 2016). Warthog meat supplies a favorable fatty acid profile for human health concerns. Saturated fat warthog is important in the prevention of coronary diseases and control cholesterol levels in humans (Hoffman and Sales, 2007).

Warthogs are not endangered, but are considered nuisance to farmers because they damage crops and can carry diseases contagious to domestic livestock (Fowler, 1996; Anderson *et al.,* 1998; Nascimento *et al.,* 2011). Warthogs have been deliberately eradicated from African agricultural areas, because they can carry and transmit African swine fever together with the soft tick vector (*Ornithodoros porcinus*), which are fatal to domestic pigs and other livestock (de Oliveira, 2013; Darfour–Oduro, 2015; Swanepoel *et al.,* 2016). Warthogs also host tsetse flies and and carriers sleeping sickness, which is deadly to humans (Anderson *et al.,* 1998; Jori and Bastos, 2009). The common warthogs are also potential wildlife reservoirs of *bovine tuberculosis* (Musoke *et al.,* 2015). Common warthogs are usually killed (Fig.13) byAfrican lions (*Panthera leo*) and leopards (*Panthera pardus*) (Vercammen and Mason, 1993; Hjertlöv, 2015). Cheetahs (*Acinonyx jubatus*), African wild dogs (*Lycaon pictus*) and spotted hyenas (*Crocuta crocuta*) are potential predators of warthogs (White and Cameron, 2008; Kahana *et al*., 2013).Relative to other savanna ungulates, common warthogs lack speed and endurance to escape their predators (Treydte *et al*.,

2006). When the animals are vigilant to predators, they often retreat with tails held erect and energetically defend their enemies (White, 2010).They also move back to burrows and lay low in thick forest cover (Cilliers, 2002; White and Cameron, 2008; Jori and Bastos, 2009).

Figure 13. Common warthog carcass in the study area (Photo: Alemayehu Edossa, 2017).

Currently, common warthogs are not a protected species, and many populations are in serious decline in many parts of African countries (Gandiwa, 2011). Today, they are listed as least concern by IUCN (Treydte *et al*., 2006). Warthogs are also usually killed, as a source of bushmeat and illegal hunting of warthog are very common in African countries (Gandiwa, 2011; Martin *et al.,* 2012; Wilfred, 2012; Nielsen *et al.*, 2013). Large parts of the African wilderness are being turned into farmland and fenced for protection of cattle and humans (Hjertlöv, 2015).

Warthogs have departed in some areas where the human population is growing, and in some countries found only in protected areas (Treydte *et al*., 2006). The extent of habitat for wild animals is decreasing and most animals get restricted to wildlife reserves (Kahana*et al.*, 2013). Human persecution in reprisal for crop–raiding, or overhunting for meat (Plate 2) anthropogenic activities are probably the most important threatsto common warthog (Vercammen and Mason, 1993; Cumming, 2005;Hjertlöv, 2015). All these factors lead to a great impact on the natural ecosystem and force the animals gradually to be exterminated (Kahana*et al.*, 2013; Hjertlöv, 2015).

3. OBJECTIVES

3.1. General objective

The general objective of the present study was to investigate population estimates and behavioral ecology of the common warthog in Dabena Valley Forest (DVF); Buno Bedelle Zone,western Ethiopia.

3.2. Specific objectives

- To assess abundance, density and distribution of common warthog in the DVF (Gassi Controlled Hunting Area (GCHA) and Haro Aba Diko Controlled Hunting Area (HADCHA)
- to identify habitat typesthat common warthog population usein GCHA and HADCHA
- to describe the major activity patterns of common warthogsin both study areas
- to assess feeding ecologyof common warthogs
- to assess the main nutrients that common warthogsuse
- to calibrate nutrient quality ingested by common warthogs in GCHA and HADCH, and
- toidentifymajor threat of common warthogs in the study areas.

3.3. Research hypotheses

- Common warthog population size differs between GCHA and HADCHA and season.
- Habitat association of common warthogs varies seasonally in both the study areas
- Activity patterns of common warthogs vary between sexes, seasons and in the time block of the day in both study areas
- Common warthogs forage higher proportion of grasses than browses in both study sites during wet and dry seasons.
- Nutrient quality that common warthog utilize vary between season and study areas
- Soil ingested by common warthog comprises important macro and micro nutrients
- Crop raiding is the main causes of human common warthog conflict in GCHA and HADCHA

4.THE STUDY AREAS

To facilitate the study, Dabena Valley Forest (DVF) was divided into two. The western side of DVF was named Gassi Controlled Hunting Area (GCHA) and the eastern side, Haro Aba Diko Contolled Hunting Area (HADCHA). The Dabena River borders the two.

4. 1.Gassi Controlled Hunting Area (GCHA)

Gassi controlled hunting area (GCHA) is located in the Oromia Regional State of the Buno Bedelle Administrative Zone of Ethiopia. It is approximately 600 km west of Addis Ababa along Addis Ababa Bedelle –Mettu road inthe western lowland of the country. Gassi Controlled Hunting Areais situated in the southwestern part of Dabena Valley Forest (DVF), between 8^{o} 39' 15'' – 8^{o} 52' 30'' N latitude and35^{o} 55' 30'' – 36^{o}7' 15'' E longuitde,with an elevation ranging from 1,538 to 1689m asl(Fig.14).Gassi and Miesso rivers give out their main water to Dabena River (Fig.15). Dabena Valley Forest is situated within the Didessa River sub basin. Didessa River is the second catchment area of Abay basin next to Dabus the largest drainage of the upper Blue Nile River Basin (Fitsum Merid, 2002; Seleshi Bekele Awulachew *et al.,* 2007). Didessa and Dabus Rivers drain the southwestern part of the basin, and contribute about one third of the total flow of the Grand Ethiopia Renaissance Dam (Betrie *et al.,* 2011) and the main sediment source of the Nile River (Ali, 2014). Gassi controlled hunting area wasdemarcated as a controlled hunting areain 2007 G. C. with an estimated total area of 24,000 ha including savannawoodlandand riparian forest.

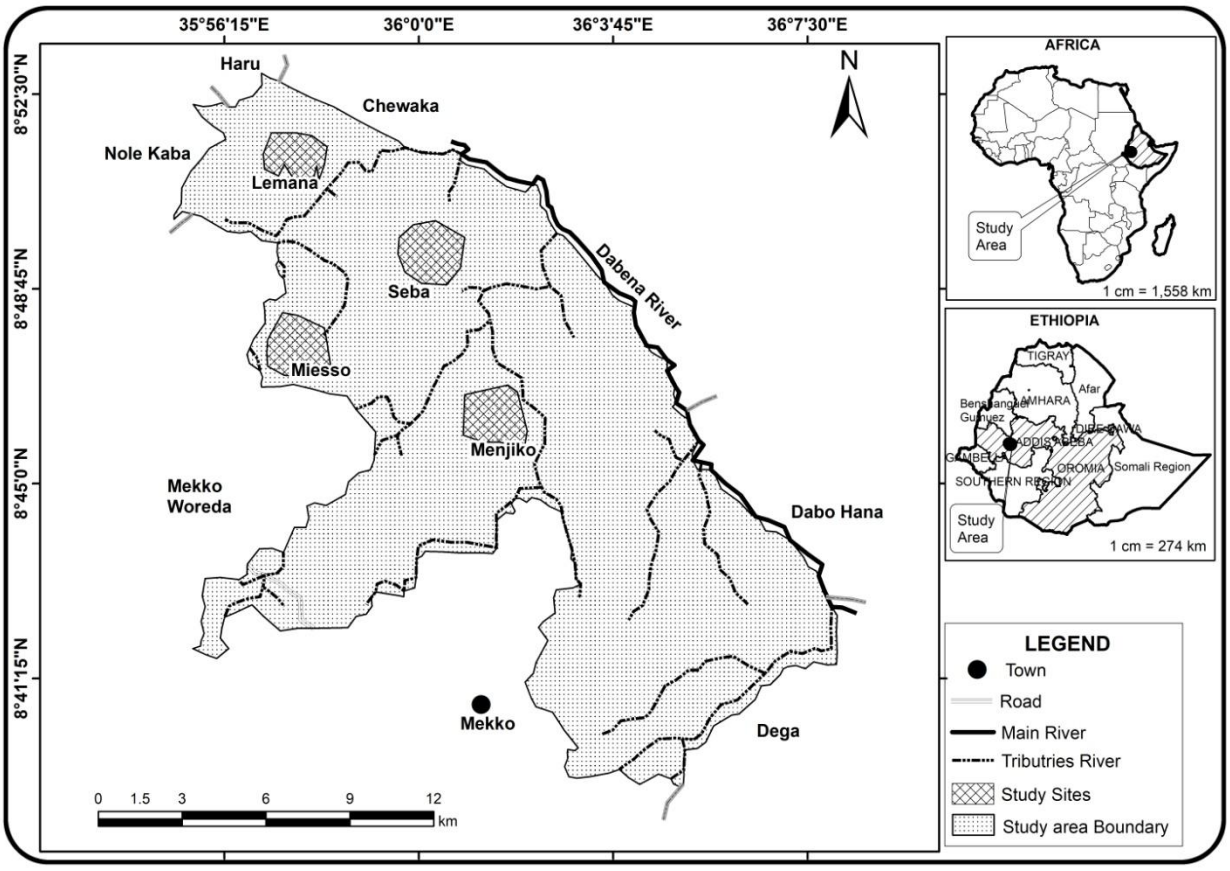


Figure 14. Location map of Gassi controlled hunting area.

Figure15. Dabena River down the Lemana site (Photo: Alemayehu Edossa, April 2018).

Meteorological data were collected from Mekko Woreda National MeteorologicalAgency station, which is 25 km away from GCHA. The study areais characterized by tropical savanna zone (*kola*) climatic condition and receives a unimodalannual rainfall. The wet season is short and extends from June to October with the highest rainfall between June to August. The dry season is longer and ranges from November to May.The mean annual rainfall of the area from 2007 to 2017was 1536.6 mm, with the highest mean monthly rainfall recorded inAugust (370.6 mm) and the lowest in December (13.3 mm). The mean monthly maximum temperature recordedwas 32.3^{o}C in Mayand the mean minimum was 11.5^{o}C in December(Fig. 16).

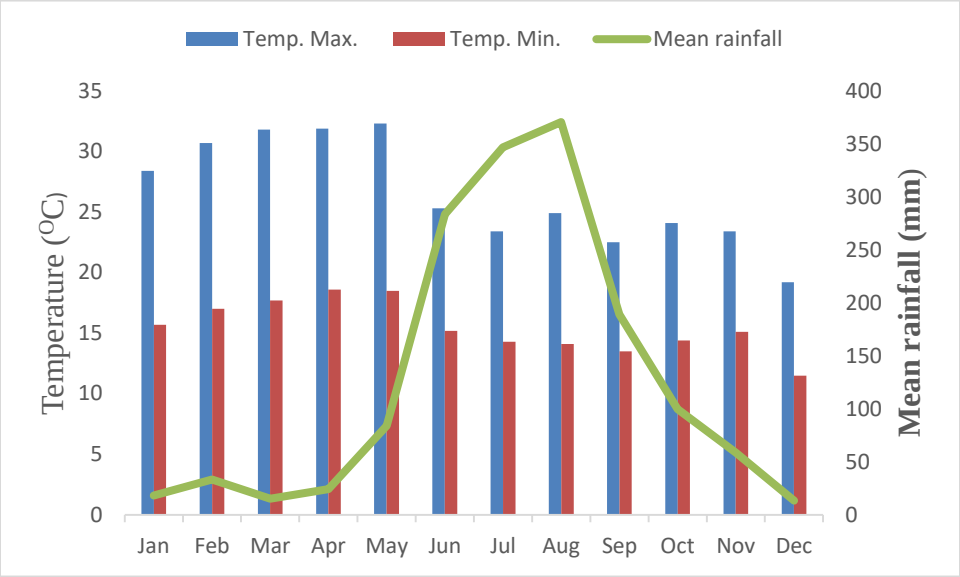


Figure 16. Monthly mean minimum and maximum temperature (^{o}C) and rainfall (mm) in GCHA from 1997 to 2017 (Source: National Meteorological Agency of Ethiopia).

4. 2.Haro Aba Diko Controlled Hunting Area (HADCHA)

Haro Aba Diko contolled hunting area is located in the Oromia Regional State, Buno Bedelle Administrative Zone of Ethiopia. It is approximately 550 km west of Addis Ababa along the Addis Ababa Nekemte Gimbi road in the western lowland of the country. Haro Aba Diko contolled hunting areais situated in north–eastern part of DVF between 8^{o} 35’ 20’’ – 8^{o}45’ 55’’ N latitude and 36^{o} 15’ 45’’– 36^{o}20’ 10’’ E longitude, with an elevation ranging from 1,646 to 1,720m asl(Fig. 17). HADCHA was demarcated in 2007 G.C with an estimated total area of 53,841 ha including savanna woodland and riparian forest. It is one of the controlled hunting areasin the western Ethiopia that could be used as the future carbon sequestration center of the country.

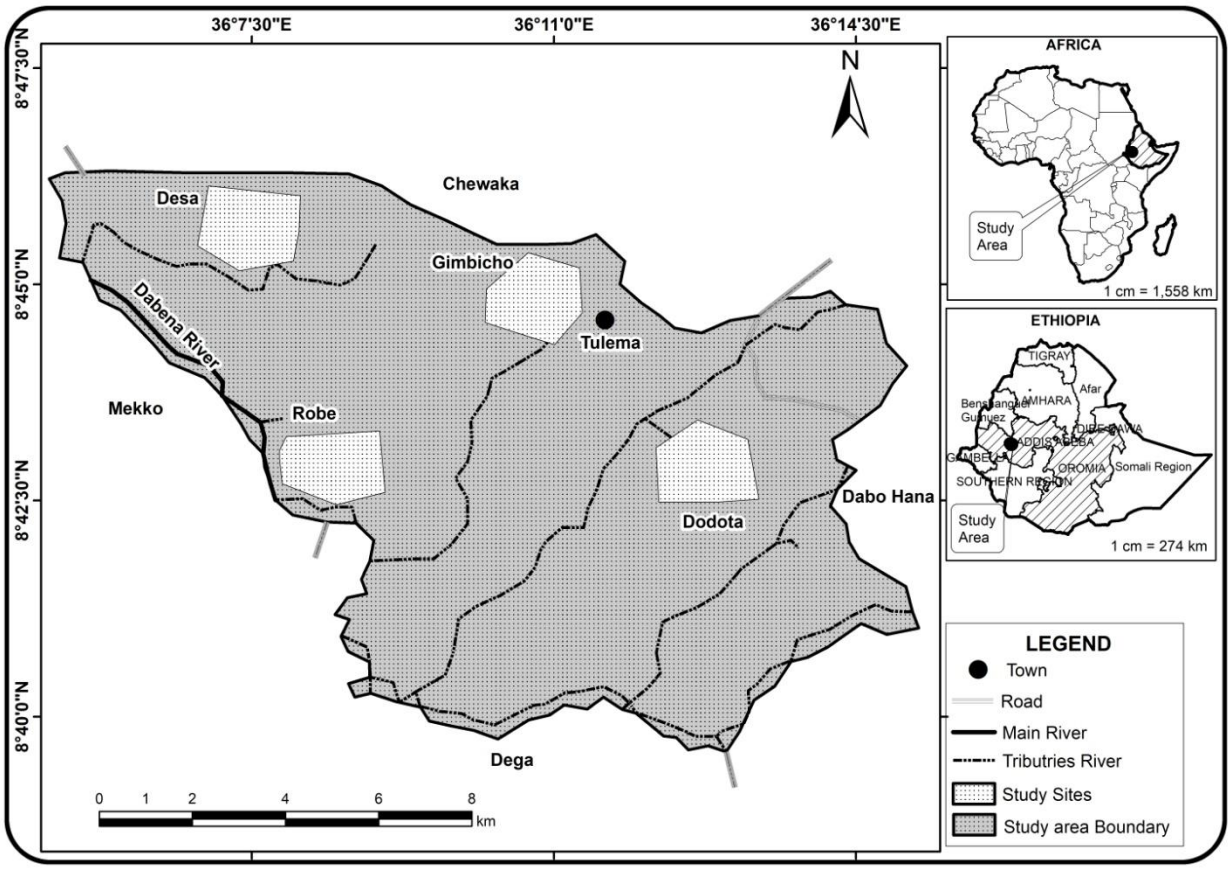


Figure 17. Location map of Haro Aba Diko contolled hunting area

Meteorological data were collected from Kone National Meteorological Agency station, which is 32 km away from HADCHA. This study is characterized by tropical savanna zone (*kola*) climatic condition and receives a unimodal annual rainfall. The wet season is short and extends from June to October with the highest rainfall between June to August. The dry season is longer and ranges from November to May. The mean annual rainfall of the area from 2007 to 2017 was1434.1 mm, with the highest mean monthly rainfall recorded in August (285.4 mm) and the lowest in December (15.9 mm). The mean monthly maximum temperature was 35.2^{o}C recorded in May and the mean minimum was 12.3^{o}Crecorded in January (Fig. 18).

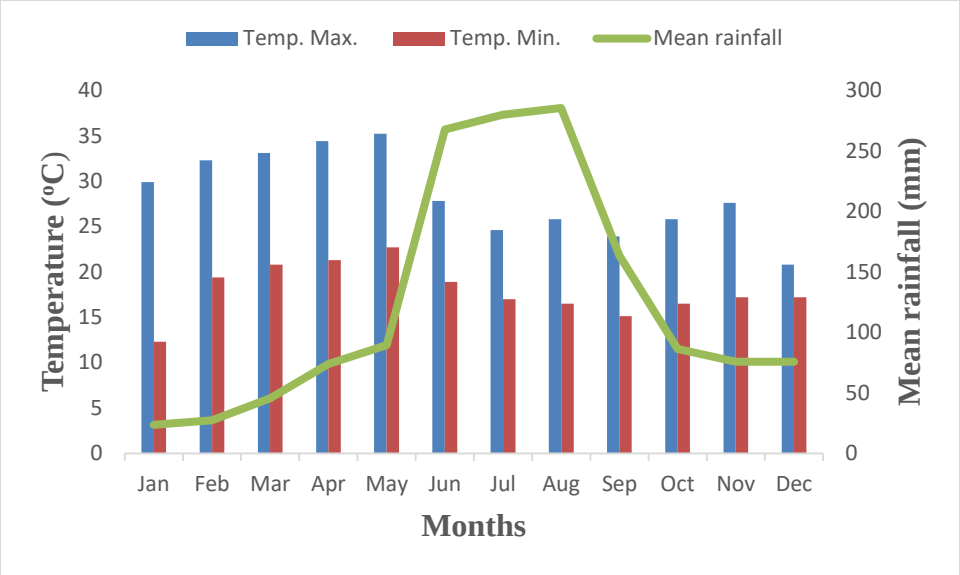


Figure 18. Monthly mean minimum and maximum temperature (^{o}C) and rainfall (mm) in HADCHA from 1997 to 2017 (Source: National Meteorological Agency of Ethiopia).

Dabena Valley Forest (GCHA and HADCHA) is characterized by *Combretum–Terminalia* woodland or savanna ecosystem (IBC, 2005; Zewde Achiso, 2014). *Combretum–Terminalia* woodland ecosystem is one of the nine ecosystems of Ethiopia documentedbythe Institute of Biodiversity Conservation (IBC) of the country (IBC, 2009; Friis *et al.*, 2011). This ecosystem is described by small to moderate–sized tree species with broad leaves, often deciduous and occurs between 500 and 1,900 m. a. s. l. (IBC, 2005; Zewde Achiso, 2014). Savanna vegetation is characterized by a high level of structural heterogeneity. This heterogeneity is mainly the effect of small–scale variation in canopy cover, which in turn exerts by biophysical processes(Holdo and Mack, 2014).

Combretum– Terminalia ecosystems haswide socioeconomic importance regarding land–use and biodiversity (Bergman*et al*., 2014; Baudena *et al.*, 2015), soil and watershed protection (Olupot *et al.*, 2009). Several plant species of this ecosystem have medicinal values (Eloff *et al*., 2005;

Friis *et al.,* 2011). These include extract ofleaves of*Combretum micranthum*, *C. molle*and*Terminalia arjuna* (Masoko and Eloff, 2007; Lima *et al.,* 2012; Mariod *et al.,* 2014; Begum *et al.,* 2016) and powdered roots of *C. erythrophyllum, T. stenostachya*, and*T. Chebula* (Friis *et al.,* 2011; Mbwambo *et al.,* 2011; Fahmy *et al.,* 2015). People around the study areas hang honey hives over savanna trees to collect honey (Fig.19). The ecosystem is also a source of wild honeyin the opening of treesmade by bees (Plate 3), wild edible fruits (Plate 4), forest coffee, incenseand *Aframomum corrorima.*

Figure 19. Honey hiveshanged over savanna tree inGCHA (Photo Alemayehu Edossa April, 2018).

In *Combretum–Terminalia* woodland ecosystem,the vegetation is influenced by seasonal fire (IBC, 2005; Zewde Achiso, 2014). The majority of woody species are well adapted to fire with

mortality rates below 5%. Susceptibility to fire by these species decline with age (Liedloff *et al.,* 2001). Therefore, savanna is among the most fire–prone biomes on earth, resilient and characterized by coexistence of both tree and grass biomass mixtures (Furley *et al.,* 2008; Holdo *et al.,* 2009; Moustakas *et al*., 2009;Treydte *et al.,* 2010; Baudena *et al.,* 2015). Fire in the savanna stimulates different phases of plant life cycles, including seed dispersal, flowering, and seed germination in fire–pronevegetation (den Bergh, 2008; Bowman and Murphy, 2010; Nepolo and Mapaure, 2012). Perennial herbs and grasses, which include lilies, orchids and other bulb plants effectively flower following fire, and flowering in these plant triggered by one of the ingredients of smoke such as ethylene (Bond and Keeley, 2005). In many fire prone environments, seeds are usually enclosed in woody fruits and open only after a fire event of serotiny (den Bergh, 2008; Bowman and Murphy, 2010; Nepolo and Mapaure, 2012). In the savanna ecosystem, fire is the major cause for nutrient losses mainly from tall grasses (Holdo *et al.,* 2007; Cech, 2008; van der Werf *et al.,* 2010). The study areas are rich in fauna diversity (Habte Jebessa, 2015). Dabena River Valley encompasses different medium, sized and large mammalian species (Appendix I). Some large herbivores including common warthog and other ungulates of the study areas interacts with fire activity (Ripple *et al.,* 2015). High levels of grazing by these animals usually reduce fire frequency and enable woody plants to escape the "fire trap" and increase in dominance (Furley *et al.,* 2008; Bowman and Murphy, 2010).

Currently, the natural *Combretum–Terminalia* woodland ecosystem is limited to special locations in the country. Over exploitation of *Combretum* and *Terminalia* spp.and the encroachment of *Acacia* species in the *Combretum–Terminalia* woodland ecosystem threatening the small coverage of this ecosystem (Friis *et al.,* 2011). Moreover, human resettlement, lowland

crop especially sesame and overgrazing are becoming threats to the *Combretum–Terminalia* woodland ecosystem (IBC, 2005; Friis *et al.*, 2011). Wildlife hunting and habitat destruction are also among the major threat of this ecosystem.

5. MATERIALS AND METHODS

5. 1. Materials

Materials used during the study period include binoculars, clinometer,digital camera, GPS, measuring tape, data sheets, compass, beam balance, digging materials, microscopic slide, dry cell and battery camera traps.

5. 2. Methods

5.2.1. Population abundance

Dabena Valley Forest comprises HADCHA and GCHA. Data on population abundance of common warthog were collected from eight randomly assigned study sites: Robe, Desa, Gimbicho, and Dodeta in HADCHA and Miesso,Seba, Lemana and Menjiko sites in GCHA. These sites were randomly selected and surveyed during the wet and dry seasons of 2016 to 2018 study periods. A total of 64 transect lines, eight from each study sitesrandomly assigned and covered on foot (Azhar *et al.*, 2008; Forsyth and Lange, 2012). In *Combretum–Terminalia* woodland habitats the transect lines were ranging between 1.95 to 2.00 km, in riparian forest habitatsit varied between 0.65 to 0.7 km andin the open grassland it was between 0.85 to 0.90 km length in both study areas. The total distance walked was 40.746km in GCHA and 42.144 km in HADCHA (Appendix II and III). The length and number of transect lines were designed for comparative purposes of common warthogs population abundance and density in *Combretum–Terminalia* woodland,riparian forest and open grassland habitats in both study areas.

Transect studies were conducted during the wet and dry seasons of the study period. Track lines were located separately ranging from 10 to 200m apart to avoid double counting of individuals.The beginning and the end of each transect was marked using GPS (Azhar *et al.,* 2008; Bekhuis *et al.,* 2008; Wanyama *et al*., 2009). The transect width was limited to 25m,for maximum visibility in *Combretum–Terminalia* woodland and riparian forest habitats (Horcajada– Sanchez and Barja, 2015) and 50m in the open grassland (Desbiez*et al.,* 2009). Data were collected twice a day from 06:00 h to 10:00 h and 16:00 h to 18:00 h During the dryseason,DVFpossessed partlyimpenetrable vegetation and its landscape was characterized by topographic ruggedness.

Ability of individual to detect the animal, fatigue, lack of concentration, and physical features of the survey area and weather conditions were assumed to affect observers' abilities of detecting animals (Kühl *et al.,* 2008; Horcajada–Sanchez and Barja, 2015). In order to overcome the aforementioned constraints and to increase precision, adequate training on data collection was given for data collectors. The center of length and the edge of the line transects were predetermined and marked using rope and colored indicators (Marques *et al.,* 2001). Observers walked along each strip line transect and recorded all common warthogs within a distance ''w'' of the line, where ''w'' is the fixed half–width of strip line transect (Thomas *et al*., 2009; Morelle *et al*., 2012). To avoid any bias, fixed transect widths were applied for all transects irrespective of local differences of visibility (Griffiths, 1978).

Group sizes of common warthogs whose center were on or very near the strip line transect were detected using binoculars and naked eyes (Wanyama *et al*., 2009; Strindberg, 2012; Denes *et al.,*

2015).All individuals of them at zero distance or at their initial location from the sampling transect line were counted before they moved towards or away from the observers (Pollock *et al.,* 2002; Kühl *et al.,* 2008; Corlatti *et al*., 2017). The detection function where g (*0*) = 1 at zero meters all the animals on the line were detected with a probability of 1 (Buckland *et al.* 2010; Forsyth and Lange, 2012; Horcajada– Sanchez and Barja, 2015). Population structure (approximate sex and group categories) was recorded (Appendix III). Common warthogs exhibit a marked level of sexual dimorphism, where adult males possess larger bodies than adult females (Swanepoel, 2016). Body size,shoulder height and tusk size or lengths were used to determine the approximate age (White, 2010; Swanepoel, 2016). Sexual characteristics, presence and absence of teats and body size were used to determine sex. Adult females were usually with one or more juveniles.

The perpendicular or radial distance of the detected sounders from the surveyed transect line was also recorded and exact measurement of the detected warthog from the line to the center was taken (Thomas *et al.,* 2007; Nasi and Vliet, 2012; Nichols and Karanth, 2012). Clinometer was used to measure the sighting angle "θ" of detected common warthog (Nielsen *et al.,* 2005; Walter *et al.,* 2013; Sjøblom, 2015). Detection distances ''r'' and detection angles ''θ'' were used to calculate perpendicular distances ''X'' as ''*X''* = r sin θ to estimate common warthog abundance (Thomas *et al.,* 2002; Thomas *et al*., 2009).The cluster size (along a line transect), and the perpendicular distances of these observations to the transect line were used to estimate the detection function and, hence, "*p* in turn allowed to estimate density and abundance of common warthog (Morelle *et al*., 2012; Denes *et al.,*2015; Corlatti *et al*., 2017). Therefore, population abundance estimation($\hat{N}$) in *i*th clusterwasusedbelow according to Buckland*et al.* (2004).

$$\hat{N} = \sum_{i=1}^{n} \frac{1}{\hat{P}_i} \hat{E}[s].$$

An estimate of the mean cluster size *E*[*s*] is given by:

$$\hat{E}[s] = \frac{\sum_{i=1}^{n} s_i / \hat{P}_a(\underline{z}_i)}{\sum_{i=1}^{n} 1 / \hat{P}_a(\underline{z}_i)}$$

An estimate of the overall abundance of common warthog in the surveyregion ($\hat{N}$) was calculated using the following equation

$$\hat{N} = \frac{A}{2Lw} \hat{N}_s = \frac{A}{2L} \sum_{i=1}^{n} s_i \cdot \hat{f}(0 \mid \underline{z}_i).$$

Where,*si* =denotes the size of the *i*th detected cluster,*Pa* (*zi*) = (f (0)/*zi*is the estimated probability of detection for the *i*th detected cluster, *Ns*= cluster of abundance, *Ncs*= total number of clusters within the covered strips, A= surveyed area, L= total transect length, w = effective strip width or truncation distance (sighting distance)

Density and abundance are related as $N = D \times A$. Hence, cluster density of common warthog was operated following Thomas *et al.* (2002) ; Buckland*et al.* (2004) and Strindberg(2012) as:

$$\hat{D} = \frac{C\hat{E}(s)}{\hat{p}2wL}$$

Where, D=cluster density, C or *n* = number of sightings

Variability in the estimated density and abundance is caused by observed sample size *C* or encounter rate *n/L*, and detection probability $\hat{P}$ or equivalently $\hat{f}(0)$ were reduced by

stratification and estimated the detection function separately by strata respectively (Griffiths, 1978; Strindberg, 2012).Variance assumed caused by estimated expected group size $\widehat{E}(s)$ decreased using binocular. Stratification by habitat type was grassland, *Combretum–Terminalia* and riparian forest whereas stratification by group types included adult males and females, sub adult male and females and unidentified sexof juveniles data of population where also stratified by seasons and recorded in the data sheet (Griffiths, 1978; Strindberg, 2012).

5. 2.2. Habitat association of common warthogs

In the present study, the distribution of common warthog population in GCHA and HADCHA was associated with three vegetation zones along a transect line running from a grazing land into the savanna (*Combretum–Terminalia* woodland). Hence, habitat types throughout the study areas were classified qualitatively following the surveycarried out during the first weeks of the study period.

1. *Combretum–Terminalia*habitat: This habitat type mainly comprises small to moderate–sized trees with fairly large deciduous leaves (Fig. 20). These include: *Ficus*, spp ,*Borassusa ethiopum*, *Salix mucronata* ,*Anogeissus leiocarpa*, *Boswellia papyrifera* (Yetan Zaf), *Enatada africana*, *Stereospermum kunthianum*, *Terminalia brownii*, (Weyba),*Combretum* and *Lannea* (IBC, 2005; USAID, 2008). Some *Combretum* and *Terminalia* species are widely used in traditional medicine against malaria, bleeding, diarrhea, diabetes digestive disorders and inflammation (Mariod *et al.*, 2014; Begum *et al.*, 2016) and as a food source of warthog. In this habitat, 36 transect lines were laid to assess the common warthog population in GCHA and HADCHA.

Figure 20. *Combretum–Terminalia* woodland habitat in HADCHA (Photo by Alemayehu Edossa April 2017).

2. Riparian forest habitat: This habitat consists of the prominent solid–stemmed lowland bamboo, *Oxytenanthera abyssinica* (Shimel) and different species of hydrophilic big trees witha combination herbs like *Justecia* spp., *Barleria spinisepala.*, *Eulophia* spp., *Chlorophytum tetraphyllum*, *Hossolunda opposita* and *Ledeburia* spp. (IBC, 2009; Zewde Achiso, 2014). It also possesses *Sesbania sesban,Commelina benghalensis, Dracaena steudneri* and *Stephania abyssinica.*In riparian forest habitat,14 transect lines werelaid to study the distribution of warthogs in both study areas(Fig.21).

Figure 21. Riparian forest habitat in GCHA (Photo by Alemayehu Edossa, April 2017).

3. Open grassland habitat: This comprises fire sensitive and drought tolerant graminoid species. These include: *Hyparrhenia*spp., *Cynodon*, spp., and*Cyperus* spp.whichwere the most abundantly occurred graminoid species in the study areas. Many of these grass species usually dry and local residents fire the area during March and April of dry season (Fig. 22) and dominate the study areas toward the end of the rainy season. In this habitat 12, transect lines were laid to assess common warthog population in GCHA and HADCHA.

Figure 22. The investigator recording encounter rate recording in burnt savanna grasses in GCHA during the dry season (March 2017).

Data of common warthog population were collected through direct observations from the established transect lines from each habitat type. Transect studies were repeated every month of the wet and dry seasons. The track lines were located separately ranging 10to 200m apart to avoid double counting of individuals and the beginning and the end of each transect was marked using GPS (Azhar *et al.*, 2008; Bekhuis *et al.*, 2008; Wanyama *et al*., 2009). Data were collected twice a day from 06:00 to 10:00 h and 16:00 to 18:00 h.Thus, common warthog population group size, population category and sexes observed were recorded.

Common warthog population abundance and densities were analyzed following the methods of Buckland *et al*. (2004), Thomas *et al*. (2007) and Thomas *et al*. (2010). Confidence interval and coefficient of variations were used to measure precision and variability of common warthog population abundance and density. Common warthog population per transect was analyzed using M±SE and one way analysis of variance (ANOVA), which were used to test differences in the mean of common warthog population of each study sites and habitat types (Jha *et al.,* 2011; Kahan *et al*., 2013). Tukey test was used for multiple comparisons of eachof this study sites and habitat types to identify the differences existed in the number of common warthog populations after a one–way ANOVA test. Mann–Whitney U test was used to compare differences between two sounders of common warthog populations across each study sites (Thomas *et al*., 2009; Buckland *et al.* 2010). Chi–square ‘’goodness of fit" was used to test how likely that observed common warthog population distribution data fits with the distribution of expected common warthog population. The variations of common warthog sounder size and individual number encountered during the wet and dry seasons were analyzed using Chi–square test (χ^2) (Buckland *et al*., 1993; Thomas *et al*., 2007; Kühl *et al.,* 2008).

5.2.3. Activity pattern

Diurnal activity patternsof common warthogs werestudied in DVF from December 2017 to June 2018 including wet and dry seasons. Observations on diurnal activity patterns were made using naked eyes and field binoculars. The duration of each activity was measured using mobile electronic stopwatch. Each day was divided into three time blocks: morning (7:00 –10:00 h), midday (12:00 – 14:00 p.m) and afternoon (15:00 –18:00 h). Continual scan sampling methods were used as adopted by Ryan and Jordaan (2005), Jian–bin *et al.*(2006) and Shannon *et al.*

(2008) to assess the activity budgets of common warthog populations. Eight separate focal sample observations sites were randomly selected (Altmann, 1974). Four sightings were in *Combretum–Terminalia*and two were in each ofthe grassland habitats and riparian forests. Focal animal observation was facilitated in the animal's preferences for short grass areas during the wet season and on the newly growing grasses after fire during the dry season by sitting on strategic sites on elevated places and tree branches. When the observed animal disappeared from view, the time interval that the animals being watched out of sight wasrecorded and another individual was randomly selected and monitored (Ryan and Jordaan, 2005).

Frequent activities of male and female common warthogs in each sounderwere detected and recorded on the data sheet at ten minutes intervaltime (Shannon *et al.,* 2008). Infrequent activities such as defecation, urination, alarm calling, and others were rejected to handle the major once. Thus, a total of 1, 024 observations of daily activities of male and female common warthog were made during the wet and dry seasons of the study period. Daily activity data were collected from 16 common warthogs populations, 8 from each sex. Daily time budget of both sexes were calculated by summing all observations per day.

The percentage of time engaged in the six main behaviors were calculated for each individual male and female of common warthogs by dividing the number of incident of a particular behavior by the total number of sightings within that time block (Jian–bin *et al.,* 2006; Shannon *et al.,*2008). The behavioral data were then organized across all the sites and averaged for each sex and season.

$$\frac{\Sigma \text{ (recorded activity X)}}{\Sigma \text{ (recorded of all activities)}} \times 100\%$$

The following were the main behaviors observed

1. Feeding – stand/walk and eat

2. Resting – lying on the ground

3. Walking/ running– moving and override

4. Vigilance– watchfulness and careful observation of the animal, whilst standing, assumes an alert posture and stares fixedly on a specific point with both ears forward; the animal may produce an alarm snort or stamp the ground with one leg.

5. Salt licking– digging the ground

6. Wallowing– rolling in the mud: undulating in water containing ground

Time spent by adult males and females dedicated to the six main behavioral activities during the three time blocks were compared using M±SE with the data pooled for both seasons and sex (Shannon *et al.,* 2008). ANOVA was used to evaluate the mean duration of time engaged in the major behavioral activities.Tukey test was used for multiple comparisons of each behavioral activity and identified the difference existed in behavioral activities after a one–way ANOVA test. The percentage and mean time attained of eachmajor behavioral activities of adult common warthog individuals during the wet and dry seasons were calculated using Chi–square test. It also identified the behavioral variation found between the two study areas (Ryan and Jordaan, 2005; Shannon *et al.,* 2008).

5.2.4. Feeding ecology

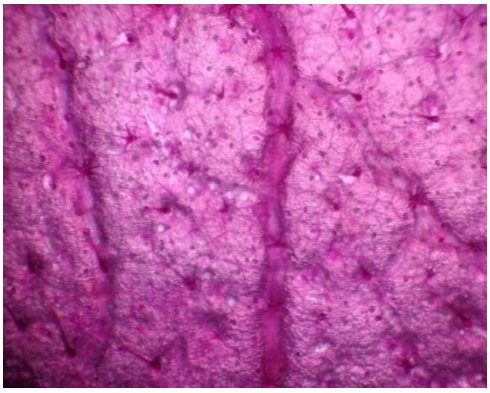
Diet composition of common warthog was determined using feeding quadrat method (Grobler, 1983; Magome *et al.*, 2008). In the feeding stations where common warthog foraged grasses and herbs, 1 x 1m quadrats were surveyed (Bullock, 2006).In shrubs foraging sites 1 x 10m quadrats were analyzed as recommended by Greenwood and Robinson (2006). A total of 1152 quadrats were laid in the area where common warthogs were observed feeding plant materials and in the feeding sites were confirmed by scars of plant and fresh fecal deposit made by common warthog (Augustine, 2004; Krebs, 2006; Ahrestani*et al.*, 2012). Feeding stations spaced 5m apart for grass species, which were assumed to be independent (Macandza *et al*., 2004). For remaining forged plant species,quadrats were spaced at 15 to 20m intervals in the feeding sites of the animal. Each day, 15 to 20 quadrats were surveyed and all plant species consumed by common warthog were collected (Macandza *et al*., 2004; Arsenault and Owen–Smith, 2008) and this was repeated every month of the study period. All of the plant species within each quadrat were identified and both recent and fresh grazing sites were noted.Fresh plant materials, which were cut during 2017 and 2018 dry and wet seasons of the study periods, pressed for the preparation of reference slides, seasonal nutrient quality measurementand identification purposes(Macandza *et al*., 2004).From HADCHA, 45 and from GCHA 41 plant materials were collected for the preparation of reference slides.Plant species foraged by common warthogs were grouped into four forage categories: graminoids, herbs, shrubs and climbers. It was assumed that all of these plant species had an equal chance of being foraged (Tshabalala *et al.*, 2009). Based on the plant species foraged by the common warthog, dietary contribution, availabilityand acceptability were determined (Wentzel *et al.*, 1991; Venter and Watson, 2008; Muposhi *et al.*, 2014). Acceptability of forage species was categorized as high (>0.5), moderate (0.3 to 0.5) andlow (< 0.3) as

explained by Macandza *et al.* (2004) and Strauss (2015). All reference slides of these forage species were prepared in the laboratory.

Prepared slides offoraged species were put under the microscope and all the diagnostic features were recorded by photomicrography. Photomicrographs of these slides were keptto identify the plant fragments observed in common warthog fecal droppings (Johnson *et al.,* 1983; Henley *et al.,* 2001; Bekhuis *et al.,* 2008).Some photomicrographed forage species used as references during fecal analysis are given in Plate 5.

Cyodon dactylon

Hyparrhenia ruf



Hibiscus macranthus

Stephania abyssinica

Plate5. Photomicrographs of forage species used as references during fecal analysis.

B.Fecal materialanalysis

Diet composition surveywas also supported by microhistological analysis of common warthog population (Storr, 1961; Mcinnis *et al*., 1983; Rumble and Anderson, 1993; Moheb, 2008).The microhistological analysis method of determining diet from feces is based upon differences among plant species in the shape and arrangement of epidermal cells(Stewart 1967; Holechek, 1982; Treydte *et al.,* 2006). Thus, from HADCHA, Robe, Desa, Gimbicho, and Dodeta and from GCHA, Miesso, Seba, Lemana and Menjiko siteswere randomly designed for data gathering plots. Fecal samples were collected twice a day from 06:00 – 10:00 h and 14:00 –18:00 h from the home ranges of common warthogs. Five fecal samples were collected from each study plot (Barancekova *et al.,* 2010). Altogether, 320 fresh fecal samples, which were less than two days old, weighing 70 g (Bekhuis *et al*., 2008) were, collected (Fig. 23) during wet and dry seasons of 2018. Some fecal samples consisted of partly undigested crops such as maize (*Zea mays,*), sorghum (*Sorghum bicolor*), teff (*Eragrostis tef*), wheat (*Triticum aestivum*) and dagusa (*Eleusine coracana*) that helped the identification process (Plate6). Fecal samples of the same season of the year were pooled to form two composite samples. Fecal samples were dried under shade and preserved in 70% ethanol during field collection (Vavra and Holechek, 1980; Johnson *et al.,* 1983; Bekhuis *et al.,* 2008). Fecal samples were ground through a Wiley mill over a 1.0 mm mesh sieve prior to treatment (Vavra and Holechek, 1980; Johnson *et al.,* 1983; Cain III *et al.,* 2017). Microhistological analysis was carried out in the laboratory from each composite fecal sample. Thirty–two (Wet= 16; Dry= 16) slides were examined using compound light microscope (Morrison, 2008).

Figure 23. Investigator collectingfresh fecal samples of common warthog in HADCHA (October 2017)

Counting and identification of epidermal fecal fragments laid inside the field of view including cell size and shape of cell wall, stomata size, stomata shape and orientation, parallel veinsand silica were identified with the help of reference slides, photographed and recorded in the data sheet (Appendix III) (Stewart, 1967; Cuartas and Garcia–Gonzalez, 1996; Gutbrodt, 2006; Morrison, 2008; Zweifel –Schielly *et al.,* 2012; Cain III *et al.,* 2017). Plant particles that did not match with the reference collections were termed as "unidentified–1, unidentified–2, and unidentified–3, unidentified–4. unidentified–5unidentified–6'' (Moheb, 2008).

For each slide, the percentage frequency for each diet component was calculated (Johnson *et al.,* 1983; Mclntire and Carey, 1989; Murphree, 2012) and frequency of occurrenceof forage species was determined. A total of 45from HADCHA and 41from GCHA different plant species

including unknown grasses and browse observed in the feces of common warthog were identified. Plant species that contributed3% or more were considered as staple diet of common warthog population (Tshabalala *et al.,* 2009). During this study, browse species refer to herbs, shrubs and woody plants, whereas the family *Poaceae* and *Cyperaceae* were grouped under graminoids (Steuer *et al*., 2010). Therefore, plant materials and microhistological analysis for determination of diet composition of common warthog population were conducted at the Animal Biotechnology Laboratory of HoletaNational Biotechnology Center.

Seasonally foraged species were analyzed using mean ± SE and one–way ANOVA.The percentage composition of different forage species categories of common warthogs were analyzed using Chi square test (Treydte *et al.,* 2006). The relative occurrences of microscopic fragments counted were analyzed by dividing the number of identified fragments of each plant to the total number of identified fragments of all plant species and multiplied by 100 (Sparks and Malechek, 1968; Mclntire and Carey, 1989). Seasonal dietary contribution was computed as the ratio each forage species utilized by common warthog to the total number of all forage species. Seasonal forage availability was calculated by dividing the number of microscopic slides in which the species was found by the total number of microscopic slides examined (Venter and Watson, 2008). The ratio of the number of quadrats in which common warthog was consumed to the total number of quadrats in which a common warthog recorded was used to compute acceptability (Owen–Smith and Cooper, 1987; Muposhi *et al.,* 2014). The differences in seasonal dietary contribution,availability and acceptability variation in the percentage contributions ofdifferent forage categories to the diet of common warthog were calculated using Chi–square

test (Muposhi *et al.,* 2014). Pearson Correlation Coefficient (r) was used to test the relationship between fecal analysis methods and feeding quadrat survey (Hauke and Kossowski, 2011).

Salt licking data were collected from eight randomly allocated study sites. These include: Robe, Desa, Gimbicho, and Dodeta sites from HADCHA and Menjiko, Seba, Messio and Lemana sites from GCHA. Top soil samples licked by common warthog were taken from 2.5 cm diameter, 20 cm deep soil cores, from five evenly spaced locations around the periphery of the central 60x60m grid in each feeding plot (Nielsen *et al.,* 2005; Goheen *et al.,* 2013). All samples from each feeding plot were pooled and thoroughly mixed for each study sites. A total of 32 kg soil samples were collected during the dry and wet seasons of 2017 and 2018 study periods. Soil collected from study plots were marked using GPS (Azhar *et al.,* 2008; Bekhuis *et al.,* 2008; Wanyama *et al*., 2009). Soil samples were dried under shade for one week and then kept at 28^{o}C until analyzed. Samples were homogenized and sieved through 2–mm mesh (Ritchie *et al.,* 1998; Augustine *et al,*. 2003; Goheen *et al.,* 2013). Soil samples were analyzed at the Soil laboratory of Holeta National Agricultural Research Center (van der Waal, 2010).

Total N and C and nutrient content of P, Na, K, Ca, and Mg of soil samples ingested by warthogs were analyzed by inductively coupled plasma spectroscopy (Augustine *et al,*. 2003;Treydte*et al.,* 2006; Lameed and Adetola, 2012; Goheen *et al.,* 2013). One–way ANOVA was used to test the differences between the chemical properties of the geophagical soils of the study sites (Lameed and Adetola, 2012).Chi–square was used to analyze seasonal differences of ingested soil and data of descriptive statistics were presented as mean ± SE (Matsubayashi *et al.,* 2006; Ping *et al.,* 2011).

5.2.5.Nutrient quality

Seasonal variations of foraging quality of common warthogs were measured using plant materials, which were sampled seasonally during the wet and dry seasons of 2017 to 2018 study periods based on procedures mentioned earlier. The clipped plant samples were dried undershade and milled through a 0.75–mm screen (Treydte *et al.,* 2006; Zweifel –Schielly *et al.,* 2012). Fecal analysis was also used to get better information about common warthog's diet quality (Treydte *et al.,* 2006; Ahrestani *et al.,* 2012) because fecal analysis studies of plant fragments revealed which plant species were consumed by the animal (Stewart, 1967).A total of 320 fresh fecal samples, which were less than two days old each weighing about70g (Bekhuis *et al.,* 2008) were collected during the wet and dry seasons of 2017and 2018 study periods and processed. The neutral detergent fiber (NDF), acid detergent fiber (ADF) and total nitrogen contents of all fecal samples and plant materials were analyzed at the Nutrition Laboratory of Holeta Agriculture Research Center. Crude protein (CP). Phosphorous and organic carbon contents of foraged plants and feces were analyzed at the Nutrition Laboratory of Ethiopian Public Health Institute Addis Ababa.

The content of NDF was measured after digestion with α–amylase and ADF were determined according to the Association of Analytical Communities (AOAC) International (Zweifel –Schielly *et al.,* 2012). Crude protein (CP) content was measured using Kjeldhal method and their concentration were estimated by multiplying the nitrogen concentration value by 6.25 (Buys, 1990; Gutbrodt, 2006; Ahrestani *et al.,* 2012). Phosphorus was determined by wet digestion and measured by a spectrophotometer (Codron *et al.,* 2005).Carbon compositionwas determined using a Carlo–Erba elemental analyzer (NCS 2500; Carlo–Erba, Milan, Italy). N, P, and

Ccontents of plants and feces wereusedas total dry matter percentages(Treydte *et al.*, 2006).Seasonal variations in diet and patterns of diet changes were tested using a Chi–square test and One –way ANOVA (Muposhi *et al.*, 2014).

5.2.6. Threat and status of common warthog population

Sample size was determined using probability proportional to sample size sampling technique (Cochran, 1977; Bartlett and Chadwick, 2001).P = 0.2 (proportion of population which was included in sample size, Q = 1–P (0.8); N = total number of population;D= ($\sigma\hat{p}$) degree of accuracy desired (0.05) was used for the survey, n= sample size (Bartlett andChadwick, 2001).

$$\sigma_{\hat{p}}^2 = \frac{1}{n} \cdot \frac{N-n}{N-1} \cdot PQ$$

$$n = \frac{NPQ}{\sigma_{\hat{p}}^2 \cdot (N-1) + PQ}$$

The total number of house holds living around and in the buffer zone of GCHAwas380 (Gassi N= 200 and Kodi N=180 and around and in the buffer zone of HADCHA was 470(Chamen N= 250 and Bereda N=220). Based on Cochran (1977) population correction factors, a total of 168 respondents were selected using simple random sampling techniques from the entire population. Allocations of the number of respondents in each study areaswas proportional to the number of respondents living in each study area. Accordingly, from GCHA (Gassi M=25, F=14 and Kodi M=25, F= 12) and from HADCHA (Chamen M= 27, F= 15 and Bereda M=34, F=16) respondents were randomly assigned for questionnaire to conduct a survey study of threat and conservation status of common warthog population. The questionnaire was mainly designed to

identify major threats of common warthogs and set to check whether people living in and around the study areas had positive attitude toward common warthogs or not. It was also designed to assess conservation need of the animals in the study areas. The questionnaire included both open ended and fixed response questions. Open ended questions were included to elicit information on the knowledge ofwildlife in the study areas (see Appendix V).

Common warthog population status, its major threats, attitudes of local people towards the animals, level of crop damage and opinion of respondents towards conservation action were analyzed using percentage statistics. Variationsthat existed among different parameters were analyzed using Chi–square ($\chi 2$) test.

6. RESULTS

6.1. Population abundance

The mean number of common warthog population in GCHA per transect was 2.69 ± 1.82 and 5.01 ± 3.0 during the wet and dry seasons, respectively. There was no significant difference ($F_{3\ 28} = 1.51$, $P > 0.05$) in the wet season and ($F_{3\ 28} = 1.14$, $P > 0.05$) in the dry season in the number of common warthog population per transect. On the other hand, there was significant difference in the mean number ofcommon warthog population ($F_{1\ 6} = 8.17$, $P < 0.05$) per transect between the wet and dry seasons of the study area. Moreover, during the wet season, the Tukey test confirmed a significant difference ($P < 0.05$) between Miesso and Seba, Lemana and Seba and Menjiko and Seba sites. However, Tukey test showed no significant difference ($P > 0.05$) between other multiple comparisons of the study sites during the wet season. Similarly, during the dry season, it indicated a significant difference ($P < 0.05$) between all multiple comparisons of the common warthog study sites except between Miesso and Seba, and Menjiko and Seba was observed ($P > 0.05$) (Table 1).

Table 1. Common warthog population recorded from each transect in GCHA (w= wet season; d= dry season, Tran. leng= Transect length)

Study Site	Season	Mean±SE	Transects								Total	Tran. leng in km
			1	2	3	4	5	6	7	8		
Miesso	w	2.13±1.69	2	3	4	1	0	2	5	0	17	10.26
	d	4.63±3.16	6	8	10	4	0	5	3	1	37	10.26
Seba	w	3.75±1.98	2	7	6	5	4	2	1	3	30	10.19
	d	5.75±3.45	5	11	10	8	3	2	6	1	46	10.19
Lemana	w	1.88±1.36	3	2	0	4	1	0	2	3	15	10.126
	d	3.25±1.98	5	3	4	5	2	0	1	6	26	10.26
Menjiko	w	3±2.24	3	2	7	6	2	1	3	0	24	10.17
	d	6.38±3.63	9	4	11	14	5	1	7	0	51	10.17
Total	w	2.69±1.82									86	
	d	5.01±3.0									160	
G. total											246	40.746

In HADCHA, the mean number of common warthog population per transect was 8.22 ± 3.8 and 12.16 ± 4.9 during the wet and dry seasons,respectively. There was no significant difference ($F_{3\ 28} = 2.65$, $P > 0.05$) during the wet and ($F_{328} = 1.02$, $P > 0.05$) dry seasons in the number of common warthog population per transect. There were a significant difference ($F_{1\ 6} = 6.79$, $P < 0.05$) in the mean number of common warthog population per transect between the wet and dry seasons of the study area. During the wet season, the Tukey test confirmed a significance difference ($P < 0.05$) between all multiple comparisons of warthog study sites except between Desa and Dodeta ($P > 0.05$). Similarly, during the dry season, the Tukey test realized a statistical

difference ($P < 0.05$) between all multiple comparisons of the study sites.However,it showed insignificant difference ($P > 0.05$) between Gimbicho and Dodeta study sites (Table 2). Besides these, the two study areas were significantly different ($F_{1\,6} = 18.51$, $P < 0.05$) during the wet ($F_{1\,6} = 39.86$, $P < 0.05$) and during the dry seasons in the number of common warthog population per transect. Transects laid in HADCHA revealed higher number of common warthog population (w=263, d=389) than GCHA (w=86, d=160) (Tables 1 and 2).

Table 2. Common warthog population recorded from each transect in HADCHA(w= wet season ; d = dry season, Tran. leng= Transect length)

Study site	Season	Mean±SE	Transects								Total	Tran. leng in km
			1	2	3	4	5	6	7	8		
Robe	w	5.13±2.62	5	9	8	1	7	5	4	2	41	10.84
	d	9.63±4.09	13	14	9	5	15	11	7	3	77	10.84
Desa	w	8±4.42	2	11	13	6	4	9	15	4	64	10.54
	d	12.13±5.22	7	14	18	11	9	12	19	7	97	10.54
Gimbicho	w	11±4.74	3	13	16	12	5	11	18	10	88	10.41
	d	13.25±5.91	9	20	20	16	7	19	11	4	106	10.41
Dodeta	w	8.75±3.63	8	4	10	16	5	7	8	12	70	10.35
	d	13.63±4.41	11	9	16	22	13	7	15	16	109	10.35
Total	w	8.22±3.8									263	
	d	12.16±4.9									389	
Gr. total											652	42.144

In GCHA, common warthog population cluster size ranged between1–7 during the wet and 1–10 during the dry seasons. The highest mean observed cluster size (MOCS) of common warthog

population recorded was from Seba (3.75±0.98) followed by Menjiko (3±1.12) during the wet season. The least recorded from Lemana, followed by Miesso. Similarly, during the dry season, the highest MOCS warthogs documented was from Menjiko (6.38±1.62), followed by Seba (5.75±1.72). On the other hand, all study sites had higher MOCS of common warthogs during the dry season than during the wet season. Themean observed cluster size (MOCS) and mean expected cluster size (MECS) of the entire study sites showed significant variation ($P < 0.05$) during both seasons (Table 3).

In HADCHA, common warthog population cluster size varied between 1– 11 during the wet and 3 –20 during the dry seasons. The highest mean observed cluster size (MOCS) of common warthogs population recorded from Gimbicho (11±2.37) followed by Dodeta (8.75±1.81) during the wet season. The least recorded was from Robe study sites. Similarly, during the dry season, the highest MOCS warthogs populationrecognizewas from Dodeta (13.63±2.21), followed by Gimbicho (13.25±2.5). On the other hand, all study sites had higher MOCS of common warthogs during the dry season than during the wet season. Themean observed cluster size (MOCS) and mean expected cluster size (MECS) of the entire study sites showed significant variation ($P < 0.05$) during both seasons (Table 3).

Table 3. Common warthog MOCS±SE and MECS±SE in both study areas during the wet and dry seasons

Study area	Study site	Wet season		Dry season	
		MOCS±SE	MECS±SE	MOCS±SE	MECS±SE
GCHA	Miesso	2.13±0.79	2.36±0.73	4.63±1.08	4.39±1.06
	Seba	3.75±0.98	3.32±0.96	5.75±1.72	6.17±1.8
	Lemana	1.88±0.78	1.79±0.71	3.25±0.91	3.33±0.92
	Menjiko	3±1.12	3.27±1.13	6.38±1.62	6.09±1.6
HADCHA	Robe	5.13±1.31	5.9±1.32	9.63±2.04	8.86±2.0
	Desa	8±2.21	8.1±2.21	12.13±2.61	12.1±2.6
	Gimbicho	11±2.37	9.7±2.21	13.25±2.5	14.55±2.3
	Dodeta	8.75±1.81	8.95±1.82	13.63±2.21	13.43±2.2

The MOCS of common warthog population was 2.69±1.59 in GCHA and 8.043±2.75 in HADCHA during the wet season. Thus, MOCS and MECS of common warthog of GCHA and HADCHA study areas showed significance variation ($F_{1\,2} = 80.98$, $P < 0.05$) during the wet season. On the other hand, during the dry season, the MOCS of common warthog populations were 5±2.65 and 12.16±4.14 in GCHA and HADCHA, respectively. But, they revealed insignificant differences ($F_{1\,2} = 3.23$, $P > 0.05$) during dry season. Haro Aba Diko controlled hunting areahad larger MOCS of common warthog population than GCHA during the wet and dry seasons (Fig.24).

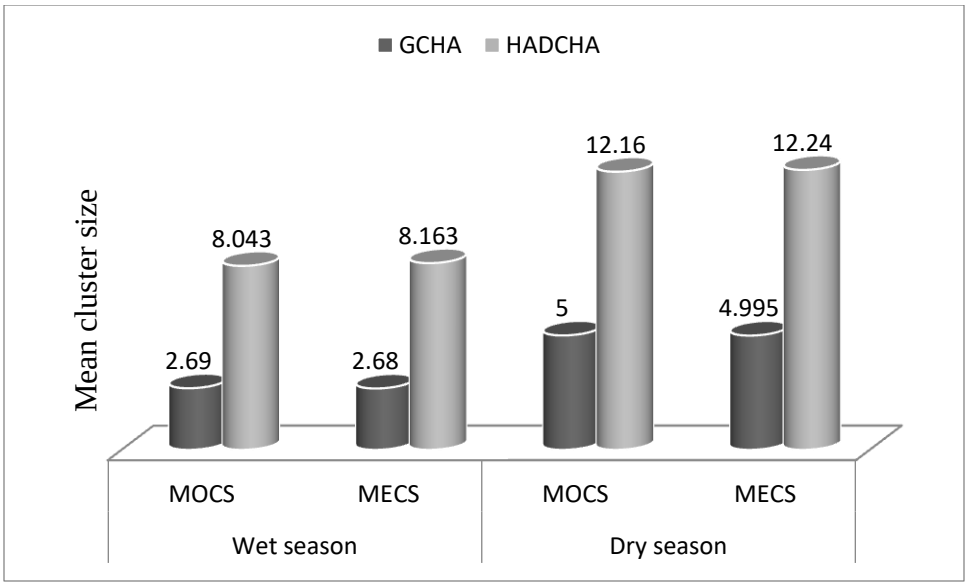


Figure24. Comparison of MOCS and MECS of common warthog of GCHA and HADCHA during the wet and dry seasons

The abundance of common warthog populations' ranged between 66–270 during the wet season in both study areas. The highest population abundance of common warthog was recorded in HADCHA study sites of Desa: 270 (CV= 55%) with a 95% CI of (289–250.7) followed by Dodeta: 257 (CV= 41%) with a 95% CI of (275–238.65). The lowest population abundance of common warthog was revealed in GCHA study sites of Seba: 76 (CV= 52.8) with a 95% CI of (81.4–70.57) and Lemana: 66 (CV= 75%) with a 95% CI of (70.7–61.28). Hence, GCHA and HADCHA study areas were significantly different ($\chi 2$ = 107.49, df = 1, P = 0.05) in the population abundance of common warthogs (Table4).

Table 4.Common warthog population abundance (N), and cluster density (CD) with 95% confidence intervals(CI) and percentage coefficient of variation (%CV) estimates in the study areas during the wet season

Study site	N	95% CI for N	CD in / km^2	95% CI for CD	% CV
Miesso	119	127.5–110.5	1.22	1.31–1.13	78
Seba	76	81.4–70.57	1.56	1.67–1.45	52.8
Lemana	66	70.7–61.28	0.79	0.846–0.73	75
Menjiko	88	94.2–81.7	1.73	1.85–1.61	74
Robe	80	85.7–74.28	2.04	2.18–1.89	51
Desa	270	289–250.7	3.13	3.35–2.91	55
Gimbicho	228	244–211.7	4.62	4.94–4.29	43
Dodeta	257	275–238.65	3.92	4.19–3.64	41
Total	1184	1268–1099			

Cluster densities of the common warthog populations' ranged from 0.79 to 4.62 /km^2 in GCHA and HADCHA during the wet season. The highest cluster density of the animal was recorded in Gimbicho: 4.62/km^2 with a 95% CI of (4.94–4.29), followed by Dodeta; 3.92 /km^2 with a 95% CI of (4.19–3.64) from HADCHA.The lowest was in Lemana: 0.79/km^2 with a 95% CI of (0.846–0.73) and in Miesso: 1.22/km^2 with a 95% CI of (1.307–1.13) study sites of GCHA. Therefore, the two study areas were significantly different ($\chi 2 = 5.33$, df = 1, P = 0.05) in cluster density estimation of common warthog during the wet season (Table 4).

Common warthog population abundance estimates of the dry season varied between 72–372 in both study areas. The highest population abundance estimate was recorded inHADCHA study

sites of Gmbicho: 372 (CV= 44%) with a 95% CI of (399–344), followed Desa: 367 (CV= 43%) with a 95% CI of (394–339.7). The lowest population abundance estimate of common warthog was found in GCHA study sites of Miesso: 72 (CV= 68%) with a 95% CI of (77–68.85) and Lemana: 104 (CV= 60%) with a 95% CI of (111–96.57). Consequently, GCHA and HADCHA study areas were significantly different ($\chi 2 = 26.06$, df = 1, P = 0.05) in population abundance estimation of common warthogs during the dry season (Table5).

During the dry season, cluster density varied between 2.1 to 5.59/km^2 in the GCHA and HADCHA study areas. The maximum cluster density was observed in Dodeta: 5.59/km^2 with a 95% CI of (5.98–5.19) followed by Gimbicho: 5.55/km^2 with a 95% CI of (5.94–5.15) inHADCHA. The minimum cluster density was found in Miesso: 2.1 /km^2 with a 95% CI of (2.24–1.95) and in Lemana: 2.08/km^2 with a 95% CI of (2.22–1.93) from GCHA during the dry season. Hence, the two study areas were significantly different ($\chi 2 = 96.75$, df = 1, P = 0.05) in cluster density estimation of common warthogs during the dry season (Table5).

Table 5**.** Common warthog population abundance (N), and cluster density (CD) with 95% confidence intervals(CI) and percentage coefficient of variation (%CV) estimates in the study areas during the dry season

Study site	N	95% CI forN	CD in /km^2	95% CI for CD	% CV
Miesso	72	77–66.85	2.1	2.24–1.95	68
Seba	156	167–144.86	2.58	2.76–2.39	60
Lemana	104	111–96.57	2.08	2.22–1.93	60.1
Menjiko	149	159.6–138	2.74	2.93–2.54	56
Robe	241	258–223.8	4.67	5–4.33	42
Desa	367	394–339.7	4.91	5.26–4.56	43
Gimbicho	372	399–344	5.55	5.94–5.15	44
Dodeta	279	299–258	5.59	5.98–5.19	32
Total	1740	1864–1616			

Common warthog population abundance estimates in GCHA was 481 (CV=32%) with a 95% CI of (515–446.65) during the dry season and 349 (CV=26%) with a 95% CI of (373.9–324) during the wet season. Hence, there was no significant variation ($\chi 2$ = 2, df = 1, P = 0.05) in the common warthogs population abundance estimates between the two seasons of the study area. On the other hand, the dry season supported higher mean of cluster density(2.37/km^2 (CV=14%) with a 95% CI of (2.9–1.84) whereas the wet season had lower mean of cluster density (1.32 /km^2 (CV=31%) with a 95% CI (1.98–0.66) in GCHA. Accordingly, common warthog

population cluster density per kilometer square showed significant variation ($\chi 2 = 15.75$, df = 1, P = 0.05) between the wet and dry seasons in GCHA (Table6).

In HADCHA,the abundance estimates of common warthog populations was 1259 (CV=40.5%) with a 95% CI of (1348.8–1169) during the dry season and 835 (CV=26%) with a 95% CI of (894–775) during the wet season. They were insignificantly different ($\chi 2 = 3.75$, df = 1, P = 0.05) between the two seasons in HADCHA. On the other hand, the dry season had more mean cluster density (5.18/km^2 (CV=7%) with a 95% CI of (5.9–4.44) than the wet season cluster density(3.43/km^2 (CV=14%) with a 95% CI (5.2–1.6) in HADCHA. Accordingly, common warthog population cluster density per kilometer square showed substantial variation ($\chi 2 = 8.42.75$, df = 1, P = 0.01) between the wet and dry seasons in HADCHA (Table 6).

Both study areas had higher abundance estimation of common warthog population (1740 (CV=53%) with a 95% CI of (1864–1616)during the dry season than 1184 (CV= 59%) with a 95% CI of (1268–1099) during the wet season. Likewise, the dry and the wet seasons of the two study areas were significantly different ($\chi 2 = 35.2$, df = 1, P = 0.001) in abundance estimation of common warthog population (Table 5). Both study areas supported higher mean cluster densityof (3.78/km^2 (CV=40) with a 95% CI of (5–2.4)) during the dry season than 2.37 /km^2 (CV=57) with a 95% CI of (3.5–1.2) during the wet season. But,the dry and the wet seasons of the study areas revealed insignificant variation ($\chi 2 = 3.69$, df = 1, P = 0.05) in common warthog population cluster density (Table6).

Table 6. Comparison of common warthog population abundance (N) and cluster density (CD) with 95% CI and %CV estimates in GCHA and HADCHA during wet and dryseasons. (w= wet season and d= dry season)

Study area	Season	N	95% CI for N	CD inkm^{-2}	95% CI for CD	% CV
GCHA	w	349	373.9–324	1.32	1.98–0.66	26
	d	481	515–446.65	2.37	2.9–1.84	32
HADCHA	w	835	894–775	3.43	5.2–2.6	26
	d	1259	1348.8–1169	5.18	5.9–4.44	40.5
Total	w	1184	1268–1099	2.37	3.5–1.2	59
	d	1740	1864–161 6	3.78	5–2.4	53

During the wet season, a total of 69 clusters of common warthog sightings were recorded from both study sites. The highest clusters of common warthog populations were recorded from Gimbicho:12 (CV=38.5%), followed by Dodeta:10 (CV=34%) in HADCHA, whereas the lowest was from Miesso:6 (CV=29%) and Lemana:6 (CV= 28.8) in GCHA. The two study sites were insignificantly different ($\chi 2$ = 2.08 df = 1, P = 0.05) in the clusters of common warthog population sightings recorded (Table7).

Common warthog encounter rate ranged from 1.1 to 3.73 per kilometerduring the wet season. The peak encounter rate was recorded in Desa:3.73/km (CV=89%), followed by Dodeta: 3.14/km (CV=59%)of HADCHA, while the lowest in Robe:1.1/km (CV= 44%) of HADCHA

and Seba:1.25/km (CV= 60%) of GCHA. The study areas were not significantly different ($\chi 2$ = 2.44 df = 1, P = 0.05) in warthog encounter rates (Table7).

Table 7. Common warthog population sightings, encounter rate and MDP±SEwith %CV during the wet season

Study site	Sightings	%CV	Encounter rate in km	%CV	MDP ±SE	%CV
Miesso	6	29	2.12	61	0.39±0.36	71
Seba	9	29.2	1.25	60	0.49±0.285	14
Lemana	6	28.8	1.32	47	0.293±0.193	74
Menjiko	9	53	1.31	83	0.43±0.246	55
Robe	8	0	1.1	44	0.54±0.141	40
Desa	9	34.6	3.73	89	0.294±0.28	66
Gimbicho	12	38.5	2.46	80	0.5±0.22	48
Dodeta	10	34	3.14	59	0.389±0.237	55
Total	69					

The mean detection probability (MDP) of common warthog population varied from 0.293 to 0.54 in both study areas during the wet season. The highest MDP was found in Robe: 0.54±0.141 (CV=40%), followed by Gimbicho: 0.5±0.22 (CV=80%). The least MDP was observed in Lemana:0.293±0.193 (CV=74%)and Desa: 0.294±0.28 (CV=66%). There was no significant difference ($\chi 2$=0.722, P= 0.05) in the detection of common warthog populations during the wet season between the study areas (Table 7).

During the dry season, a total of 73 clusters of common warthog sightings were observed from both study sites. The highest clusters of common warthog populations were recorded from Gimbicho: 10 (CV=36%), Robe: 10 (CV=34.6%)and Menjiko:10 (CV=52.8). The lowest was from Miesso:8 (CV=50%) and Desa: 8 (CV= 0%). The two study areas did not show significant variation ($\chi 2 = 0.188$ df = 1, P = 0.05) in the clusters of common warthog sightings (Table8).

Common warthog encounter rate ranged from 1.76 to 3.9 per kilometer during the dry season. The peak encounter rate was recorded from Menjiko: 3.9/km (CV=94%), followed by Seba: 2.37/km (CV=84%) while the lowest was from Miesso: 1.76/km (CV= 76%) and Robe: 1.85/km (CV= 86%). However, the study areas were not significantly different ($\chi 2 = 0.631$ df = 1, P = 0.05) in the common warthog groups encounter rate during the dry season (Table8).

The mean detection probability (MDP) of common warthog population varied from 0.207 to 0.593 in both study areas during the dry season. The highest MDP of the animal was found in Desa: 0.593±0.246 (CV=61%), followed by Gimbicho: 0.578±0.277 (CV=60%). The least MDP was observed in Lemana: 0.207±0.185 (CV=90%) and Menjiko: 0.397±0.316 (CV=75%). There was no significant difference ($\chi 2=1.1$, P= 0.05) in the detection of common warthog population during the dry season between the study areas (Table8).

Table 8. Common warthog population sightings, encounter rate and MDP±SEwith %CV during the dry season

Study site	Sightings	%CV	Encounter rate in km	%CV	MDP ±SE	%CV
Miesso	8	50	1.76	76	0.55±0.32	54
Seba	9	29.2	2.37	84	0.44±0.283	51
Lemana	9	53	2.17	96	0.207±0.185	90
Menjiko	10	52.8	3.9	94	0.397±0.316	75
Robe	10	34.6	1.85	86	0.414±0.237	50
Desa	8	0	2.72	73	0.593±0.246	61
Gimbicho	10	36	1.96	45	0.578±0.277	60
Dodeta	9	29.4	2.06	37	0.43±0.282	63
Total	73					

In GCHA, 37 sightings with CV=32% and 30 sightings with CV=23% of common warthog population were recorded during the dry and wet seasons, respectively. But they revealed insignificant variation ($\chi 2 = 3.12$, df = 1, P = 0. 05). On the other hand, common warthog mean encounter rate (MER) was 2.55/km (CV=36%) during the dry season and 1.5/km (CV=27%) during the wet season in GCHA.They showed insignificant variation between seasons ($\chi 2 = 4.2$, df = 1, P = 0.05). The MDP was 0.395(CV=35%) during the dry season and 0.4(CV=20%) during the wet season in GCHA. Mean detection probability of common warthog showed insignificant variation ($\chi 2 = 0.001$, df = 1, P = 0.05) between the wet and dry seasons in GCHA (Table 9).

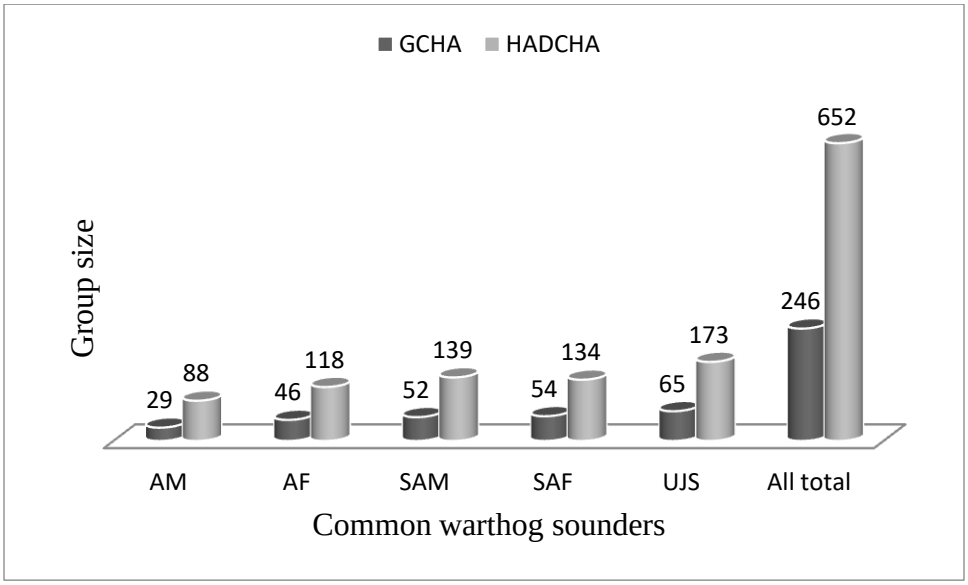
In HADCHA, 39 sightings with CV=10.5% and 39 sightings with CV=17.5% of common warthog population were recorded during the dry and wet season, respectively. They showed no significant variation ($\chi 2 = 0.26$, df = 1, P = 0. 05). In the same study area, MER was 2.14/km (CV=18%) during the dry season and 2.6/km (CV=43%) during the wet season. However, they were not significantly different ($\chi 2 = 0.59$, df = 1, P = 0.05). The MDP was 0.503(CV=18.8%) during the dry season and 0.43(CV=25%) during the wet season in HADCHA. The MDP of common warthog showed insignificant variation ($\chi 2 = 0.99$, df = 1, P = 0.05) between wet and dry seasons (Table 9).

Table9. Comparison of common warthog population sightings, MER and MDP with % CV of both study area

Study site	Season	Sightings	%CV	MER	%CV	MDP	%CV
GCHA	w	30	32	1.5	27	0.4	20
	d	37	23	2.55	36	0.395	35
HADCHA	w	39	17.5	2.6	43	0.43	25
	d	39	10.5	2.14	18	0.503	18.8
Total		145					

The largest adult male (AD) of common warthog sounder size was 88 in HADCHA and the smallest was in GCHA (29). But, they showed insignificant variation ($\chi 2 = 4.32$, df = 1, P = 0.05). Adult female (AF) group size was maximum in HADCHA (118) and minimum in GCHA (46). They revealed significance difference ($\chi 2 = 5.67$, df = 1, P = 0.05). Sub–adult male (SAM) group size was highest in HADCHA (139) and lowest in GCHA (52) and they were significantly

different ($\chi 2$ = 5.88, df = 1, P = 0.05). The maximum sub–adult female (SAF) group size was hosted by HADCHA (134) and the minimum by GCHA (54). They were significantly different ($\chi 2$ = 5.83, df = 1, P = 0.05). The largest unidentified juvenile sex (UJS) group size was recorded in HADCHA (173) and the smallest in GCHA (65). They revealed significant variation ($\chi 2$ = 6.78, df = 1, P = 0.05). All sounder size of common warthog population in GCHA was 246, in HADCHA 652 and total was 898 during both seasons. Therefore, they showed significant difference ($\chi 2$ = 18.78, df = 1, P = 0.05) (Fig.25).



AM= adult male, AF= Adult female, SAM= sub-adult male, SAF= sub-adult female,

UJE= unidentified juvenile sex

Figure25. Common warthog sounder size in GCHA and HADCHA

The highest common warthog population sounder was formed by UJS: 235(26.5%), followed by SAM: 191(21%). The lowest was by Am: 117(13%) in both study areas during the wet and dry seasons. There was a significant difference ($\chi 2$ = 16.12, df = 4, P = 0.001) among the common warthog population sounder of the study areas (Fig.26).

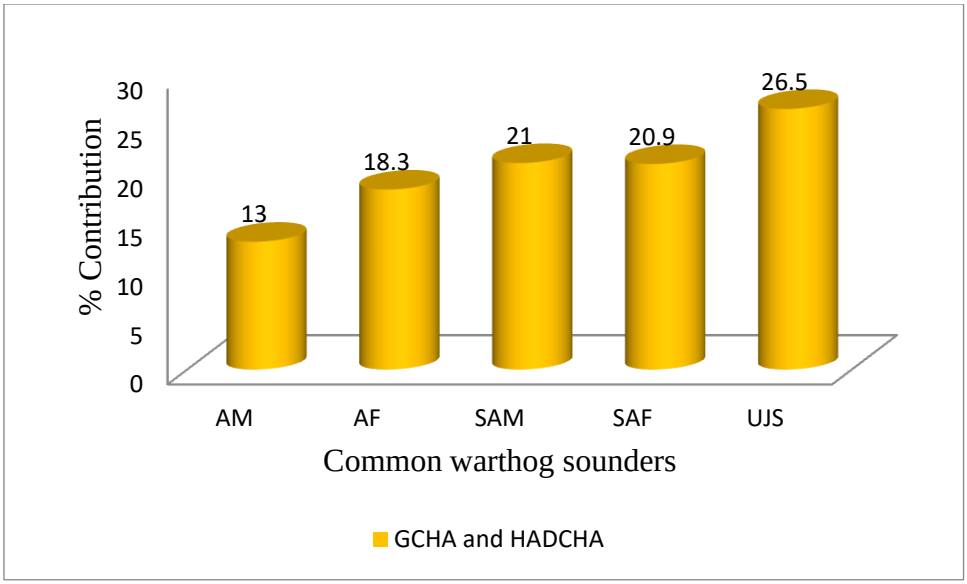


Figure26. Common warthog sounder size contribution in both study areas.

In GCHA, sounder size of adult male (AM) ($\chi 2 = 2.51$ df = 1, P = 0.05), sub–adult male (SAM) ($\chi 2 = 3.52$ df = 1, P = 0.05) and unidentified juvenile sex (UJS) ($\chi 2 = 3.11$ df = 1, P = 0.07) were not influenced by seasons. In contrast, sounder size of adult female (AF) ($\chi 2 = 5.68$ df = 1, P = 0.05) and sub–adult female (SAF) ($\chi 2 = 5.46$ df = 1, P = 0.05) were influenced by season. Post hoc comparisons revealed AF and SAF sounder size were significantly larger during the dry season than during the wet season in GCHA (Table10). During the wet season, AM common warthog population sounder size was significantly different (Mann– Whitney: U =1.5, P< 0.005) only from SAF. Sounder size of AF and SAM (U =7.5, P< 0.005), AF and SAF (U =7, P< 0.005), and AF and UJS (U =6, P< 0.005) were significantly different. In GCAH during the dry season, AM and AF, AM and SAM, AM and UJS and AF and SAM sounders were significantly different (P< 0.005) (Table 10).

In HADCHA,sounder size of AM ($\chi 2 = 2.08$ df = 1, P = 0.05), SAM ($\chi 2 = 3.07$ df = 1, P = 0.05) and SAF ($\chi 2 = 3.61$ df = 1, P = 0.05) of were not influenced by seasons. On the contrary, sounder size of AF ($\chi 2 = 5.16$ df = 1, P = 0.05) and UJS ($\chi 2 = 6.01$ df = 1, P = 0.05) groups were influenced by season. Post hoc comparisons revealed AM, AF and UJS sounder size were significantly larger during the dry season than the wet season in HADCHA (Table 10). In HADCHA during the wet season, AM and AF (U =3, P< 0.005), AM and SAM (U =2, P< 0.005), AM and SAF (U =3, P< 0.005), AF and SAM (U =4.5, P< 0.005), and AF and SAF (U =5.5, P< 0.005) sounder size were significantly different. On the other hand, soundersize of AF and UJS, SAM and SAF, SAM and UJS, and SAF and UJS were significantly different (P< 0.005). In HADCHA, the sounder size of AM and AF (U =2.5, P< 0.005), AM and SAM (U =1.5, P< 0.005), AM and SAF (U =2, P< 0.005), and AF and SAM (U =5, P< 0.005) showed significant variations during the dry season. Furthermore, AF and SAF (U =3.5, P< 0.005), SAM and SAF (U =7.5, P< 0.005), and SAM and UJS (U =2, P< 0.005) were significantly different (Table 10).

Table10.Seasonal variation in sounder size ofcommon warthog in GCHA and HADCHA

study site	Season	Sounder					Total
		AM	AF	SAM	SAF	UJS	
Miesso	w	2	5	3	3	4	17
	d	5	6	7	8	11	37
Seba	w	3	7	6	7	7	30
	d	6	8	11	10	11	46
Lemana	w	1	3	4	3	4	15
	d	3	5	5	7	6	26
Menjiko	w	2	4	5	6	7	24
	d	7	8	11	10	15	51
Robe	w	5	7	8	9	12	41
	d	10	14	16	15	22	77
Desa	w	7	11	13	12	21	64
	d	13	17	20	21	26	97
Gimbicho	w	11	16	20	18	23	88
	d	16	20	21	22	27	106
Dodeta	w	9	12	16	15	18	70
	d	17	21	25	22	24	109

AM= adult male, AF= Adult female, SAM= sub-adult male, SAF= sub-adult female,

UJE= unidentified juvenile sex

The mean number of SAF per study site was 4.75 ± 1 in GCHA and 13.5 ± 1.93 in HADCHA and UJS was 5.5 ±0.86 in GCHA and 18.5 ± 2.39 in HADCHA. Therefore, the two study areas showed significant variationsin SAF ($F_{1\,6} = 15.9$, $P < 0.05$) and in UJS ($F_{1\,6} = 26$, $P < 0.05$) per study site during the wet season. Consequently, HADCHA supported more mean numberof sounders of common warthogs than GCHA (Fig.27)

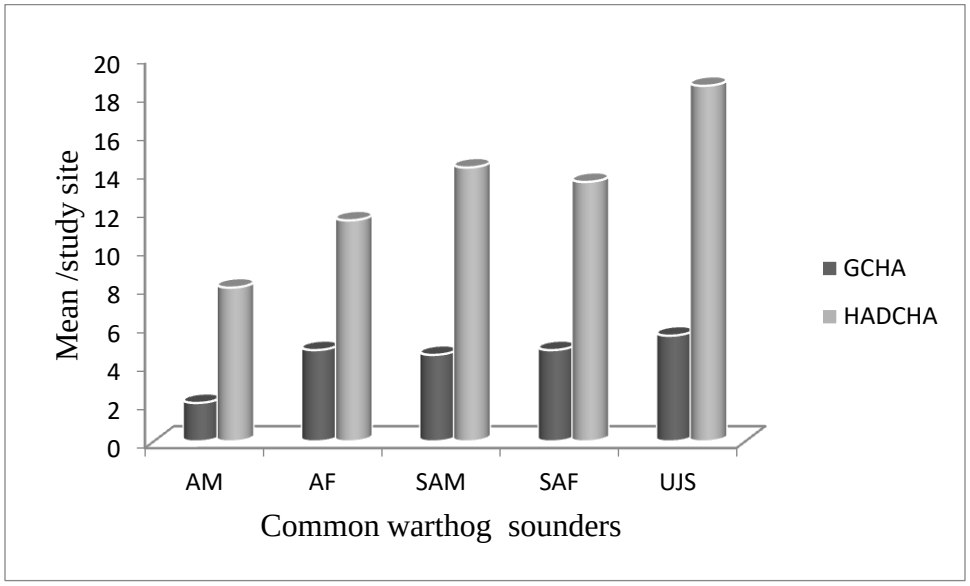


Figure27. Common warthog sounder M±SE per study site in GCHA and HADCHA during the wet season.

During the dry season, the mean number of AM common warthogs per study site was 5.25± 0.85 in GCHA and 14 ± 1.58 in HADCHA, AF was 6.75 ±0.75 in GCHA, and 18 ± 1.58 in HADCHA SAM was 8.5 ±1.5 in GCHA and 20.5 ± 1.84 in HADCHA. Thus, there were a significance difference between the study areas in AM ($F_{1\,6} = 23.71$, $P < 0.05$), in AF ($F_{1\,6} = 41.33$, $P < 0.05$) and in SAM ($F_{1\,6} = 25.41$, $P < 0.05$) sounders per study site during the dry season. Haro Aba Diko controlled hunting areahad more mean numbers of common warthog population sounders than GCHA during the dry season (Fig. 28).

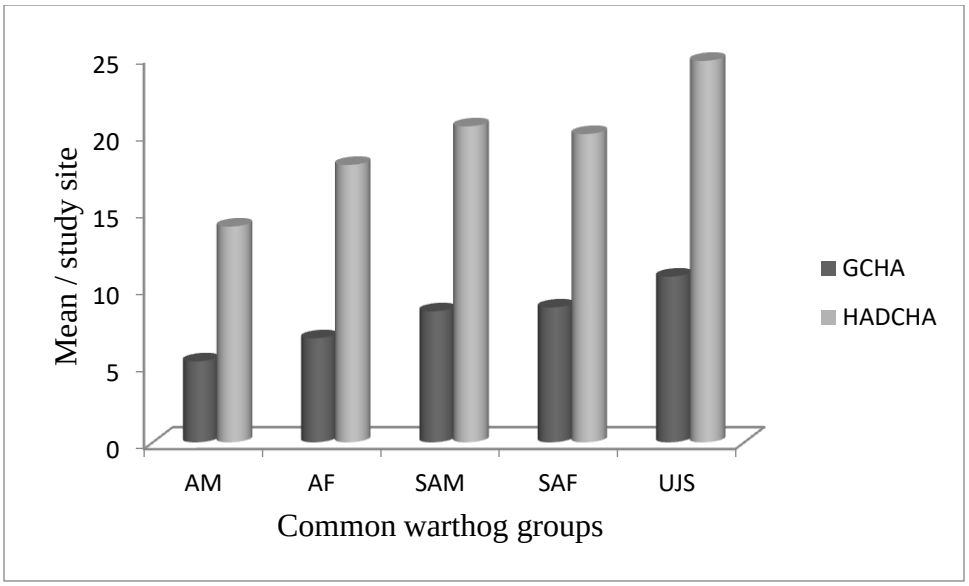


Figure 28. Common warthog sounder M±SE per study site in GCHA and HADCHA during the dry season.

6.2. Habitat association

The mean number of common warthog population that occured in *Combretum–Terminalia* was lower during the wet season (14 ± 1.63) than during the dry season (24.25 ± 4.92) in GCHA. There was a significant variation ($F_{1\,6} = 12.12$, $P < 0.05$) in the mean number of common warthog population observed in *Combretum–Terminalia* between the wet and dry seasons in GCHA. The mean number of common warthog population occurred in riparian forest was higher during the dry season (12.4.7 ± 4.92) than during the wet season (3±1.41) in GCHA. There was significant difference ($F_{1\,6} = 21.24$, $P < 0.05$) in the mean number of common warthog population observed in riparian forest between the wet and dry seasons. In the open grassland habitat, the mean number of common warthog population was 4.5±3.4 during the wet season and 8±6.7 during the dry season. There was no difference ($F_{1\,6} = 0.06$, $P > 0.05$) in the mean number

of common warthog population observed in open grassland habitats between the wet and dry seasons (Table 11).

In GCHA, the Tukey test confirmed a significant difference ($P < 0.05$) between *Combretum–Terminalia* and riparian forests, open grassland and *Combretum–Terminalia* habitats in the number of common warthog populations during the wet and dry seasons. Moreover; during the wet season, *Combretum–Terminalia* supported high number of common warthog population (56,65.11%), followed by open grassland habitat (18, 20.9%). Therefore, there wasa significant variation ($\chi2 = 8.17$, df = 2, $P = 0.05$) in the number of common warthog populations among the habitats. Similarly, *Combretum–Terminalia* hosted 97 (60.62%), and open grassland supported 32 (20%) and riparian forest had 31 (19.37%) common warthog population during the dry season. These three habitats showed a significant variation ($\chi2 = 20.49$, df = 2, $P = 0.05$) in the number of common warthog population (Table 11).

Table 11. Common warthog population recorded in different habitats of GCHA during the wet and dry seasons

Habitat type	Season	Mean±SE	Study site				Total
			Miesso	Seba	Lemana	Menjiko	
Comb– Term	w	14± 1.63	14	16	12	14	56
	d	24.25± 4.92	28	26	17	26	97
Riparian forest	w	3± 1.41	3	4	1	4	12
	d	12± 4.7	9	7	6	9	31
Open grassland	w	4.5± 3.4	0	10	2	6	18
	d	8± 6.7	0	13	3	16	32
Total							246

In HADCHA,*Combretum–Terminalia* habitat had lower mean number of common warthog population during the wet season (41 ± 6.97) than during the dry season (59 ± 9.62). There was a significant variation ($F_{1\,6} = 9.17$, $P < 0.05$) in the mean number of common warthog population found in *Combretum–Terminalia* habitat between the wet and dry seasons of the study area. On the other hand, the mean number of common warthog population inriparian forestwas moreduring the dry season (17.75 ± 7.4) than during the wet season (11.25±7.27). Therewas significant difference ($F_{1\,6} = 21.24$, $P < 0.05$) in the mean number of common warthog population observed in riparian forests between the wet and dry seasons. In open grassland habitat, the mean number of common warthog population was 26.75±15.45 during the wet season and 42±23.71 during the dry season. However, they were insignificantly different ($F_{1\,6} =$

0.29, P > 0.05) in the mean number of common warthog population recorded in open grassland habitats between the wet and dry seasons (Table 12).

In HADCHA, the Tukey test showed a significance difference (P < 0.05) between *Combretum–Terminalia* and riparian forest habitats of common warthog during the wet and dry seasons. But the Tukey test did not show significance difference (P > 0.05) between other multiple comparisons of common warthog habitats. During the wet season, *Combretum–Terminalia* maintained more number of common warthog 164 (62.35%), followed by open grassland habitat 54(20.53%) and riparian forest 45(17.11%). There was significant variations($\chi 2 = 30.44$, df = 2, P = 0.05) in the percentage of common warthog populations among habitats. Similarly, *Combretum–Terminalia* hosted 236 (60.66%), open grassland 82 (21.1%) and riparian forest 71 (18.2%), of common warthog population during the dry season. The three habitats showed a significant variation ($\chi 2 = 41.68$, df = 2, P = 0.05) in the percentage of common warthog populations (Table 12).

Table 12.Common warthog population recorded from different habitats of HADCHA during the wet and dry seasons (w= wet season, d= dry season)

Habitat type	Season	Mean±SE	Study site				Total
			Robe	Desa	Gimbicho	Dodeta	
Comb– Term	w	41±6.97	33	50	40	41	164
	d	59±9.62	57	70	47	62	236
Riparian forest	w	11.25±7.27	8	4	21	12	45
	d	17.75±7.4	20	7	20	24	71
Open grassland	w	26.75±15.45	0	10	27	17	54
	d	42± 23.71	0	20	39	23	82
Total							652

During the wet season, a total of 56 (6.2%) and 164 (18.2%) common warthog populations occurred in *Combretum–Terminalia* habitat of GCHA and HADCHA, respectively. However, they were insignificantly different ($\chi 2 = 2.21$, df = 1, P = 0.05). During the dry season, a total of 97 (10.8%) and 236 (26.3%) of warthog populations found in *Combretum–Terminalia* habitats of GCHA and HADCHA,respectively. Therewas no significant variation ($\chi 2 = 1.17$, df = 1, P = 0.05) between the *Combretum–Terminalia* habitats of the two study areas. Riparian forest in GCHA had 12 (1.3%) and HADCHA had 45 (5%) common warthog populations during the wet season. There was significant difference ($\chi 2 = 8.04$, df = 1, P = 0.05) in the number of common warthog population riparian forest hosted. During the dry season, GCHA had 31(3.4%) and HADCHA had 71(7.9%) warthog population in riparian forest. Therewas no significant variation ($\chi 2 = 3.47$, df = 1, P = 0.05). Open grassland habitats in GCHA had 18 (2.0%) and HADCHA had54(6.0%) warthogs. There was significantly different ($\chi 2 = 13.58$, df = 1, P = 0.05) in during

the wet season. In open grassland habitats of GCHA had 32(3.5%) and HADCHA had 82 (9.1%) common warthog populations during the dry season. Accordingly,the two study areas were significant difference($\chi 2 = 12.47$, df = 1, P = 0.05) in the percentage of common warthog populations found in open grassland habitats during the dry season (Table 13).

Table 13. Percentage comparison of common warthog population in different habitats of GCHA and HADCHA during the wet and dry seasons

Habitat type	GCHA		HADCHA	
	Wet	Dry	Wet	Dry
Comb–Term	56(6.2%)	97(10.8%)	164(18.2%)	236(26.3%)
Riparian	12(1.3%)	31(3.4%)	45(5%)	71(7.9%)
Open grass	18(2.0%)	32(3.5%)	54(6.0%)	82(9.1%)
Total	86(9.6%)	160(17.8%)	263(29.3%)	389(43.3%)

Population abundance estimates common warthog varied between 28– 239 during the wet season and 110–247 during the dry season in GCHA. The highest population abundance estimate of common warthog was recorded from *Combretum–Terminalia*; 239 (CV= 80%) with a 95% CI (256–222), followed by open grassland; 82 (CV= 58.6%) with a 95% CI (88–76).The three habitats had significantly different ($\chi 2 = 9.84$, df = 2, P = 0.05) population abundance estimate of common warthogs during the wet season in GCHA (Table 14). Similarly, during the dry season *Combretum–Terminalia* had 247 (CV= 70%) with a 95% CI (264.6–229), open grassland had 124 (CV= 72.5%) with a 95% CI (133–115) and riparian forest hosted 110(CV= 67.8%) with a 95% CI (118–102). However, they were insignificantly different ($\chi 2 = 4.2$, df = 2, P = 0.05). The

number of common warthog population in *Combretum–Terminalia* ($\chi 2 = 0.187$, df = 1, P = 0.05) andin riparian forest ($\chi 2 = 1.12$, df = 1, P = 0.05) was not affected by season. In contrast, in GCHA,more number of warthog population occurred in open grassland habitats during the dry season (124) than during the wet season (82). There was significantly different ($\chi 2 = 18.35$, df = 1, P = 0.05) in the common warthog population abundance(Table 14).

Table 14**.** Common warthog population abundance (N) and cluster density (CD)with 95% CI and % CV estimates by habitats type in GCHA

Habitats	Season	N	95% CI for N	CD in km^{-2}	95% CI for CD	% CV
Comb. Term	w	239	256–222	2.18	2.34–2.01	80.7
	d	247	264.6–229	2.24	2.4–2.08	70
Riparian	w	28	30–26	1.25	1.34–1.16	83
	d	110	118–102	1.7	1.82–1.57	67.8
Open grassland	w	82	88–76	1.46	1.56–1.36	58.6
	d	124	133–115	2.01	2.15–1.82	72.5

During the wet season in GCHA, common warthog cluster density in *Combretum–Terminalia* was2.18/km^2 with a 95% CI of (2.34–2.01) and in open grassland it was 1.46 /km^2 with a 95% CI of (1.56–1.36).Population density of warthogs was more in *Combretum–Terminalia* habitat. Therewas significant variation ($\chi 2 = 6.18$, df = 2, P = 0.05) in population density of warthogs during the wet season. Similarly,*Combretum–Terminalia* hosted the highest cluster density (2.24 /km^2 with a 95% CI of (2.4–2.08), followed by open grassland (2.01/km^2 with a 95% CI of (2.15–

1.82) during the dry season. There was insignificant difference in common warthog population abundance ($\chi 2$ = 1.09 df = 2, P = 0.05) during the dry season. The density of common warthog population in *Combretum–Terminalia* ($\chi 2$ = 0.46, df = 1, P = 0.05), in riparian forest ($\chi 2$ = 0.78, df = 1, P = 0.05) and in open grassland habitat ($\chi 2$ = 0.52, df = 1, P = 0.05) were not affected by seasons in GCHA (Table 14).

In HADCHA, population abundance estimate ranged between 124– 440 during the wet season and 199–746 during the dry season. The highest population abundance estimate of common warthog was recorded in*Combretum–Terminalia*: 440 (CV= 64%) with a 95% CI of (471–408.5) followed, by open grassland: 271 (CV= 37%) with a 95% CI of (290–251.7) and riparian forest; 124(CV= 52%) with a 95% CI of (133–115) during the wet season. Therefore, the three habitats were significantly different ($\chi 2$ = 11.35, df = 2, P = 0.05) in population abundance estimate of common warthog (Table 15). Similarly, during the dry season *Combretum–Terminalia* had 746 (CV= 63%) with a 95% CI of (799–692.7) and open grassland had 314 (CV= 68%) with a 95% CI of (336–291.6). They showed significant variations ($\chi 2$ = 77.57, df = 2, P = 0.05). Along these, the population abundance of common warthog in *Combretum–Terminalia* ($\chi 2$ = 9.35, df = 1, P = 0.05)and in riparian forest ($\chi 2$ = 8.92, df = 1, P = 0.05) and in open grassland ($\chi 2$ = 15.28, df = 1, P = 0.05) habitats were affected by seasons. The dry season hosted more population abundance estimation than the wet season in the entire habitats (Table 15).

Table 15.Common warthog population abundance (N) and cluster density (CD)with 95% CI and %CV estimates by habitat types in HADCHA(w= wet season, d= dry season)

Habitats	Season	N	95% CI for N	CD inkm^{-2}	95% CI for CD	% CV
Comb. Term	w	440	471–408.6	4.61	4.94–4.28	64
	d	746	799–692.7	5.34	5.72–4.96	63
Riparian	w	124	133–115	2.18	2.34–2.02	52
	d	199	213–185	3.41	3.65–3.17	49
Open grassland	w	271	290–251.7	3.33	3.57–3.09	37
	d	314	336–291.6	4.26	4.56–3.96	68

Common warthog cluster density in *Combretum–Terminalia* was 4.61/km^2 with a 95% CI of (4.94–4.28), in open grassland it was 3.33 /km^2 with a 95% CI of (3.57–3.09) and in riparian forest 2.18 /km^2 with a 95% CI of (2.34–2.02) during the wet season in HADCHA. *Combretum–Terminalia* had more cluster density than the other two habitats. There was significant variations ($\chi 2 = 7.65$, df = 2, P = 0.05) during the wet season. Similarly, *Combretum–Terminalia* had the highest cluster density (5.34 /km^2 with a 95% CI of (5.72–4.96) followed, by open grassland (4.26 /km^2 with a 95% CI of (4.56–3.96) and riparian forest had (3.41 /km^2 with a 95% CI of (3.65–3.17) during the dry season. Hence, they were insignificantly different ($\chi 2 = 3.23$ df = 2, P = 0.05) in common warthog cluster density. On the other hand, the density of common warthog population in *Combretum–Terminalia,* in riparian forest and in open grassland habitat did not show significant variations ($\chi 2 = 0.1.33$, df = 1, P = 0.05), ($\chi 2 = 3$, df = 1, P = 0.05) and, ($\chi 2 = 2.08$, df = 1, P = 0.05) between the seasons, respectively (Table 15).

During the wet season, *Combretum–Terminalia* in HADCHA hosted more population estimates of common warthog (440 (CV= 64%) with a 95% CI of (471–408.6) than GCHA, which had 239 (CV= 80.7%) with a 95% CI of (256–222). Hence; they were statistically different ($\chi 2 = 30.97$, df = 1, P = 0.05) in common warthog population estimate. Similarly,riparian forest comprised more population estimates of common warthog in HADCHA (124 (CV= 52%) with a 95% CI of (133–115) thanin GCHA (28 (CV= 83%) with a 95% CI of (26–30) during the wet season. The study areas showed significant variations ($\chi 2 = 11.83$, df = 1, P = 0.05) in common warthogpopulation estimate. Open grassland habitat also maintained more warthog population in HADCHA (271 (CV= 27%) with a 95% CI of (290–251.7) than in GCHA (82 (CV= 58.6%) with a 95% CI of (88–76). Therefore; they showed significant variation ($\chi 2 = 33.94$, df = 1, P = 0.05) in common warthogpopulation estimate (Table 16).

Combretum–Terminalia had lower population estimates of common warthog in GCHA (247(CV= 70%) with a 95% CI of (264.6–229) than in HADCHA (746 (CV= 63%) with a 95% CI of (799–692.7) during the dry season. Hence; they showed significance difference ($\chi 2 = 58$, df = 1, P = 0.05) in common warthog population estimate. Riparian forest hosted lower population estimates of common warthog in GCHA (110 (CV= 67.8%) with a 95% CI of (118–102) than in HADCHA (199 (CV= 49%) with a 95% CI of (213–185). There was significant variationsin common warthog population estimate between the two study areas ($\chi 2 = 19.58$, df = 1, P = 0.05). Open grassland habitat also had smaller population abundance in GCHA (124 (CV= 72.5%) with a 95% CI of (133–115) than in HADCHA (314 (CV= 68%) with a 95% CI of (336–291.6)

during the dry season. There was significantly different ($\chi 2 = 14.64$, df = 1, P = 0.05) in common warthog population estimate between the study areas (Table 16).

Table 16. Comparison of common warthog population abundance estimate by habitat types between GCHA and HADCHA during wet and dry seasons

Habitat type	GCHA		HADCHA	
	Wet	Dry	Wet	Dry
Comb–Term	239	247	440	746
Riparian	28	110	124	199
Open grass	82	124	271	314
Total	349	481	835	1259

Combretum–Terminalia cluster density was higher in HADCHA (4.61 /km^2) with a 95% CI of (4.94–4.28) and lower in GCHA (2.18 /km^2) with a 95% CI of (2.34–2.01) during the wet season. Hence, they showed significant variations in common warthog cluster density ($\chi 2 = 6.34$, df = 1, P = 0.05).Cluster density was higher in open grassland in HADCHA (3.33 /km^2) with a 95% CI of (3.57–3.09) and smaller in GCHA (1.46/km^2)with a 95% CI of (1.56–1.36). However, the difference was insignificant ($\chi 2 = 2.08$, df = 1, P = 0.05).In the riparian forest habitat, cluster density was greater in HADCHA (2.18 /km^2) with a 95% CI of (4.94–4.28) and smaller in GCHA (1.25 /k^2) with a 95% CI of (1.34–1.16). Thus, they showed significant variation ($\chi 2 = 5.68$, df = 1, P = 0.05) during the wet season (Table 17).

Common warthog cluster density of *Combretum–Terminalia* was lower in GCHA (2.24/km^2) with a 95% CI of (2.4–2.08) and higher in HADCHA (5.34 /km^2)with a 95% CI of (5.72–4.96) during the dry season. However, they showed insignificant variation ($\chi 2 = 3$, df = 1, P = 0.05). Similarly, cluster density was smaller in open grassland in GCHA (1.7/km^2) with a 95% CI of (1.82–1.57) and greater in HADCHA (3.41/km^2) with a 95% CI of (3.65–3.17). Hence, they were significantly different ($\chi 2 = 5.08$, df = 1, P = 0.05). In riparian forest habitats, cluster density was lower in GCHA (2.01 /km^2) with a 95% CI of (2.15–1.82) than in HADCHA (4.26 /km^2) with a 95% CI of (4.56–3.96). Thus, they showed significant variations ($\chi 2 = 7.33$, df = 1, P = 0.05) during the dry season (Table 17).

Table 17. Comparison of common warthog density by habitat types between GCHA and HADCHA during the wet and dry seasons

Habitat type	GCHA		Area in km^2	HADCHA		Area in km^2
	Wet	Dry		Wet	Dry	
Comb-Term	2.18/km^2	2.24/km^2	7.73/km^2	4.16/km^2	5.34/ km^2	8.54/km^2
Riparian	1.25/km^2	1.7/ km^2	4.9/ km^2	2.18/km^2	3.41/ km^2	5.4/ km^2
Open grass	1.46/km^2	2.01/km^2	4.7/ km^2	3.33/km^2	4.26/ km^2	3.92/km^2
Total	5.44/km^2	5.95/km^2	17.33/km^2	9.67/km^2	13.01/km^2	17.86/km^2

Combretum–Terminalia maintained 18 (CV= 22%) and 21 (CV= 24%) clusters of common warthog sightings in GCHA during the wet and dry seasons, respectively. But, they showed insignificant variation ($\chi 2 = 1.02$, df = 1, P = 0.05). On the other hand, 5 (CV= 69%) and 6

(CV=50%) clusters of common warthog sightings were recorded in riparian forest during the wet and dry seasons,respectively. However, they revealed insignificant difference ($\chi 2 = 0.19$, df = 1, P = 0.05). Open grassland habitats of GCHA hosted 7 (CV=24.7%) and 9 (CV= 46.5%) clusters of common warthog sightings during wet and dry seasons, respectively. However, they did not show significant variation ($\chi 2 = 0.28$, df = 1, P = 0.05). During the wet season, the three habitats were significantly different in the clusters of common warthog sightings ($\chi 2 = 6.89$, df = 2, P = 0.05). Nevertheless, difference was insignificant ($\chi 2 = 3.7$, df = 2, P = 0.05) during the dry season (Table 18).

In GCHA, common warthog encounter rate was 1.34/km (CV=58%) and 1.65/km (CV=61%) in *Combretum–Terminalia* during the wet and dry seasons, respectively. However, insignificantly different ($\chi 2 = 0.53$, df = 1, P = 0.05) between both seasons. In riparian forest, the encounter rate was 1.46/km (CV=13%) during the wet season and 2.8/km (CV= 19%) during the dry season. But, they did not show significant difference ($\chi 2 = 1.32$, df = 1, P = 0.05). The encounter rate of open grassland was 1.99/km (CV=10.4) during the wet and 2.53/km (CV=16%) during the dry season. But, they were insignificantly different ($\chi 2 = 0.28$, df = 1, P = 0.05). The highest encounter rate during the wet season was recorded in open grassland and during the dry season in riparian forest. However, the three common warthog habitats were not significantly different ($\chi 2 = 1.82$ df = 2, P = 0.05), ($\chi 2 = 1.26$ df = 2, P = 0.05) during the wet and dry seasons, respectively (Table 18).

The MDP of common warthog population in *Combretum–Terminalia* was 0.371 (CV=26%) during the wet season and 0.448 (CV= 31.8) during the dry season in GCHA. They did not show

significant seasonal difference ($\chi 2$ = 1.02 df = 1, P = 0.05). In riparian forest, the MDP was 0.213 (CV=16%) during the wet season and 0.355 (CV=49%) during the dry season. Thus, they revealed significant variation ($\chi 2$ = 5.19 df = 1, P = 0.05). In open grassland, the MDP was 0.189 (CV=15%) during the wet season and 0.331(CV=54%) during the dry season. But, they showed insignificant variation ($\chi 2$ = 2.85, df = 1, P = 0.05). The three habitats showed significant difference ($\chi 2$ = 5.81 df = 1, P = 0.05) during the wet season and insignificant variation ($\chi 2$ = 1.64 df = 1, P = 0.05) during the dry season (Table18).

Table 18.Common warthog population sightings, encounter rate and MDP with %CV by habitat types in GCHA (w= wet season, d= dry season)

Study site	Season	Sightings	%CV	Encounter rate in km	%CV	MDP	%CV
Comb. Term	w	18	22	1.34	58	0.371	26
	d	21	24	1.65	61	0.448	31.8
Riparian	w	5	69	1.46	13	0.213	16
	d	6	50	2.8	19	0.355	49
Open grassland	w	7	24.7	1.99	10.4	0.189	15
	d	9	46.5	2.53	16	0.331	54

Combretum–Terminalia habitat had 26 (CV= 13.6%) and 23 (CV= 16.6%) clusters of common warthog sightings during the wet and dry seasons, respectively in HADCHA. But, they showed insignificant variation ($\chi 2$ = 3.98, df = 1, P = 0.05). Riparian forest,had 6 (CV= 50%) and 7 (CV=54.7%) clusters of common warthog sightings during the wet and dry seasons,respectively.

However, they revealed insignificant difference ($\chi 2 = 0.66$, df = 1, P = 0.05). Open grassland habitats in HADCHA hosted 8(CV=43%) and 7(CV= 28.5%) clusters of common warthog sightings during the wet and dry seasons, respectively. However, they did not show significant variations ($\chi 2 = 0.75$, df = 1, P = 0.05). During the wet season, the three habitats were significantly different ($\chi 2 = 5.78$, df = 2, P = 0.05) in the clusters of common warthog sightings. However, insignificantly different ($\chi 2 = 3.86$, df = 2, P = 0.05) during the dry season (Table 19).

Common warthog encounter rate was 1.97/km (CV=44%) and 1.75/km (CV=60%) in HADCHA *Combretum–Terminalia* habitat during the wet and dry seasons, respectively. However, insignificantly different ($\chi 2 = 0.33$, df = 1, P = 0.05) in common warthog encounter rate between the two seasons. In riparian forest, the encounter rate was 3.46/km (CV=80%) during the wet season and 2.32/km (CV= 66%) during the dry season. But, they did not show significant difference ($\chi 2 = 2.29$, df = 1, P = 0.05)) in common warthog encounter rate between the two seasons. The encounter rate in open grassland was 5.1/km (CV=40) during the wet and 4.1/km (CV=16%) during the dry season. However, they were insignificantly different ($\chi 2 = 4$, df = 1, P = 0.05)) in common warthog encounter rate between the two seasons. The highest encounter rate was recorded in open grassland habitats during both seasons. The three common warthog habitats were not significantly different ($\chi 2 = 3$ df = 2, P = 0.05) and ($\chi 2 = 2.3$ df = 2, P = 0.05)) in common warthog encounter rate between the two seasons during the wet and dry seasons, respectively (Table 19).

The MDP of common warthog population in *Combretum–Terminalia* habitatwas 0.433(CV=45%) during the wet season and 0.53 (CV= 47) during the dry season in HADCHA. However, they were not significantly different in the MDP ($\chi 2 = 0.45$ df = 1, P = 0.05). In riparian forest, the MDP was 0.33 (CV=75%) during the wet season and 0.36 (CV=56%) during the dry season. Thus, they revealed insignificant variation in the MDP ($\chi 2 = 0.08$ df = 1, P = 0.05). On the other hand, in open grassland, MDP was 0.42 (CV=69%) during the wet season and 0.49 (CV=78%) during the dry season. But, they were insignificantly different in the MDP ($\chi 2 = 0.22$ df = 1, P = 0.05). The habitats showed significant variation in the MDP ($\chi 2 = 5.81$ df = 1, P = 0.05) during the wet season and insignificant variation ($\chi 2 = 1.64$ df = 1, P = 0.05) in the MDP during the dry season (Table 19)

Table 19.Common warthog population sightings, encounter rate and MDP with %CV by habitat types in HADCHA (w= wet season, d= dry season)

Study site	Season	Sightings	%CV	Encounter rate in km	%CV	MDP	%CV
Comb.term	w	26	13.6	1.97	44	0.433	45
	d	23	16.6	1.75	60	0.53	47
Riparian	w	6	50	3.46	80	0.33	75
	d	7	54.7	2.32	66	0.36	56
Open grassland	w	8	43	5.1	42	0.42	69
	d	7	28.5	4.1	54	0.49	78

During the wet season, 18 common warthog sightings were recorded in *Combretum–Terminalia* habitat in GCHA and 26 sightings from HADCHA. But, they showed insignificant variation in the number of common warthog sightings ($\chi 2 = 3.52$, df = 1, P = 0.05). During the dry season, 21and 23 sightings of the warthogs were recorded in *Combretum–Terminalia*in GCHA and HADCHA, respectively. However, they did not show significant difference ($\chi 2 = 0.84$, df = 1, P = 0.05). The number of common warthog population sightings recorded in riparian forest of GCHA and HADCHA were not significantly different ($\chi 2 = 1.12$, df = 1, P = 0.05) during the wet season and ($\chi 2 = 0.25$, df = 1, P = 0.05) during the dry season. On the other hand, common warthog sightings recorded in open grassland of GCHA and HADCHA revealed insignificant variation ($\chi 2 = 2.61$, df = 1, P = 0.05) during the wet season and ($\chi 2 = 0.79$, df = 1, P = 0.05) during the dry season (Table 20).

Table 20. Common warthog sightings in GCHA and HADCHA

Habitat type	GCHA		HADCHA	
	Wet	Dry	Wet	Dry
Comb–Term	18	21	26	23
Riparian	5	6	6	7
Open grass	7	9	8	7
Total	30	36	40	37

Common warthog encounter rate in *Combretum–Terminalia* habitat was 1.34/km in GCHA and 1.97/km in HADCHA during the wet season. However, they revealed insignificant variation in the encounter rate of common warthog ($\chi 2 = 2.14$, df = 1, P = 0.05) between the study areas.

During the dry season, encounter rate in *Combretum–Terminalia*habitat was 1.65/km in GCHA and 1.75/km in HADCHA. But, they did not show significant variation ($\chi 2 = 0.02$, df = 1, P = 0.05). Similarly, common warthog encounter rate recorded in riparian forest of GCHA and HADCHA were not significantly different ($\chi 2 = 2.2$, df = 1, P = 0.05) during the wet season and ($\chi 2 = 3.25$, df = 1, P = 0.05) during the dry season. On the other hand, common warthog encounter rate recorded in open grassland in GCHA and HADCHA revealed significant variation ($\chi 2 = 7.78$, df = 1, P = 0.05) during the wet season and insignificant difference ($\chi 2 = 2.61$, df = 1, P = 0.05) during the dry season (Fig. 29).

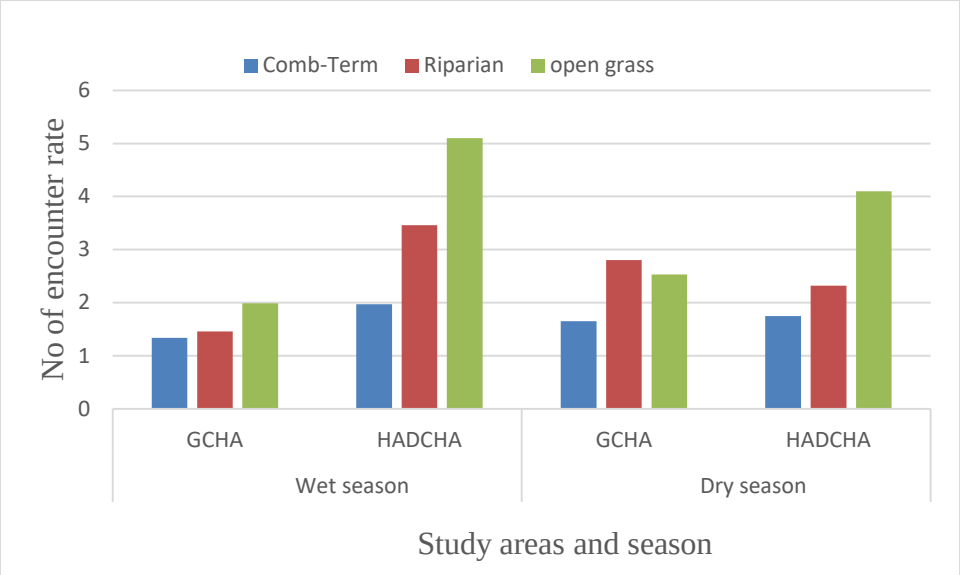


Figure29. Common warthog encounter rate in GCHA and HADCHA

Common warthog MDP in*Combretum–Terminalia* habitat was 0.371 in GCHA and 0.433 in HADCHA during the wet season. But, they showed insignificant difference ($\chi 2 = 0.37$, df = 1, P = 0.05). During the dry season, MDP in *Combretum–Terminalia*habitat was 0.448 in GCHA and 0.53 in HADCHA. However, they did not show significant variation ($\chi 2 = 0.372$, df = 1, P = 0.05). Similarly, common warthog MDP recorded in riparian forest of GCHA and HADCHA

were not significantly different ($\chi 2$ = 1.49, df = 1, P = 0.05) during the wet season and ($\chi 2$ = 0.003, df = 1, P = 0.05) during the dry season. On the other hand, common warthog MDP recorded in open grassland of GCHA and HADCHA revealed significant variation ($\chi 2$ = 11.6, df = 1, P = 0.05) during the wet season and insignificantly different ($\chi 2$ = 0.89, df = 1, P = 0.05) during the dry season (Fig. 30).

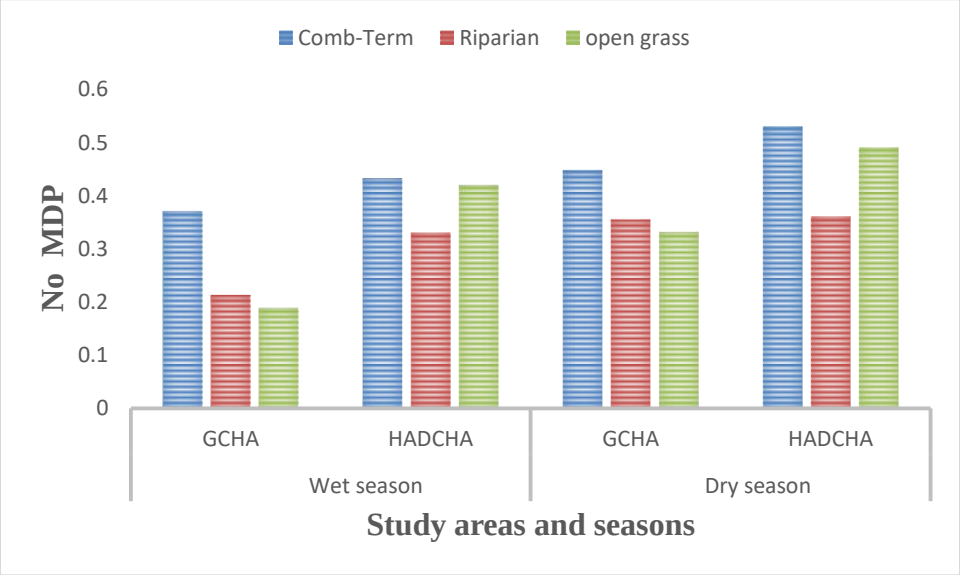


Figure 30. Common warthog MDP in GCHA and HADCHA

6.3. Activity patterns

In GCHA , the mean time adult female (AF) common warthog engaged in feeding was peaked in the morning time block in Miesso (9.25±0.36) during the wet season and it was higher in the afternoon time block in Lemana (9.12± 0.42) and Seba (9.13± 0.53) during the dry season. Resting was elevated in the midday time block in Miesso and Seba (3.62± 0.59) during the wet season and it was peaked in Menjiko (4±0.68) during the dry season. Walking was higher in the afternoon time block in Lemana (2.12 ± 0.87) during the wet season and it was maximum in

Miesso (3.37±0.56) during the dry season. Vigilance was also more in the afternoon time block in Seba (1.5±0.42) during the wet season and it was greater in the morning time block in Menjiko (2.5±0.73) during dry season. Salt licking was higher during the wet season in Miesso (1.87±0.74) in the afternoon time block and it was higher during the dry season in Lemana (2.25±0.73) in the morning time block and in Miesso (2.1±1.2) in afternoon time block. AF common warthog wallowing activity was greater during the wet season in Seba (2±1) and it was higher during the dry season in Menjiko (2.5±0.42) in the afternoon time block (Table 21).

Adult female common warthog feeding ($\chi 2 = 1.03$, df = 1, P = 0.05), resting ($\chi 2 = 3.8$, df = 1, P = 0.05) and in vigilance activities($\chi 2 = 4.56$, df = 1, P = 0.05) were not influenced by season. In contrast, walking ($\chi 2 = 8.2$, df = 1, P = 0.05), salt licking ($\chi 2 = 13.16$, df = 1, P = 0.05) and wallowing activities($\chi 2 = 15.01$, df = 1, P = 0.05) were influenced by season. All of these diurnal activity patterns were higher during the dry season than during the wet season (Table 16). Moreover, there were significant differences among diurnal activities ($F_{5\ 66} = 96.6$, $P < 0.05$) during the wet season ($F_{5\ 66} = 85$, $P < 0.05$) and during the dry season. Tukey test confirmed a significant difference($P < 0.05$) when feeding wascompared with each behavioral activities during the wet and dry seasons. But it showed no significant variation($P>0.05$) between the remaining all multiple association of the AF warthogs in GCHA (Table21).

Table 21. Diurnal behavioral activity patterns of mean ±SE of adult female common warthog in GCHA (w= wet season, d= dry season)

Study site	Season	Time block	Behavioral activities (in minutes)					
			Feeding	Resting	Walking	Vigilance	Salt licking	Wallowing
	w	7:00–10:00	9.25±0.36	0.25±0.25	1.25±0.16	0.87±0.12	0.87±0.64	0.37±0.37
		12:00–8:00	5±1	3.62±0.59	1±0.19	0.75±0.16	0.5±0.38	0
		3:00–6:00	8±0.62	2.25±0.43	1.62±0.46	1±0.33	1.87±0.74	0.75±0.75
Miesso	d	7:00–10:00	8.75± 0.36	0.62± 0.62	2.12± 0.55	1.87± 0.44	1.5± 0.76	0.62± 0.42
		12:00–8:00	4.62± 1.01	3.37± 0.69	2.87± 0.44	1.87± 0.74	1.37± 0.9	1.12± 0.87
		3:00–6:00	8.62± 0.37	2.37± 0.59	3.37± 0.56	2.25± 0.72	0.87± 0.87	1± 1
	w	7:00–10:00	9.25±0.36	0.75±0.49	1±0.19	1.12±0.58	0.5±0.26	1.25±0.84
		12:00–8:00	5.12±0.83	3.62±0.59	1.25±0.16	0.87±0.29	1±0.42	1.62±0.73
Seba		3:00–6:00	8.37±0.49	1.87±1	1.75±0.45	1.5±0.42	0.87±0.48	2±1
	d	7:00–10:00	8.6±0.48	1.5±1	2.12±0.64	2.25±0.9	1.37±0.73	1.75±0.73
		12:00–8:00	5.37±0.59	3.5±0.57	1.5±0.53	1.87±0.85	1.75±0.77	0.87±0.63
		3:00–6:00	9.13±0.53	1.75±0.72	2.75±1.2	2.25±0.82	1.25±0.55	1.75±1.16
	w	7:00–10:00	8.87±0.48	1.12±0.74	1.37±0.32	0.75±0.31	0.5±0.38	1.25±0.56
		12:00–8:00	6±0.7	3.12±0.58	0.87±0.35	0.625±0.18	1±0.57	1.37±0.56
Lemana		3:00–6:00	8.5±0.5	2.5±0.73	2.12±0.58	1.25±0.56	1.37±0.65	1.62±0.73
	d	7:00–10:00	9±0.29	0.87±0.58	2.62±0.8	1.37±0.75	2.25±0.86	1.5±0.59
		12:00–8:00	5.75±1.1	3.37±0.68	1.87±0.69	1.75±0.82	0.75±0.62	1.87±1
		3:00–6:00	9.12±0.42	2.87±0.1	2.62±0.75	2±0.78	1.87±0.74	1.25±0.41
	w	7:00–10:00	9±0.42	1±0.26	0.75±0.25	0.37±0.26	1.25±0.67	0.87±0.39
		12:00–8:00	5.5±0.73	3.5±0.92	1.25±0.52	1±0.38	1.5±0.71	0.62±0.42
Menjiko		3:00–6:00	8.75±0.49	2.87±1.1	1.37±0.53	1.25±0.52	1.87±0.69	1.62±0.73
	d	7:00–10:00	8.75±0.36	1.25±0.16	2.12±0.64	2.5±0.73	1.5±0.63	1.37±0.71
		12:00–8:00	6.25±0.77	4±0.68	1.37±0.53	1.87±0.58	1.25±0.49	1.5±0.53
		3:00–6:00	8.5±0.38	2.37±0.86	2.75±0.64	2.12±0.58	1.62±0.62	2.5±0.42

The mean duration of time adult male (AM) common warthog involved in feeding was higher in the afternoon time block in Menjiko (9±0.36) during the wet season and it was elevated in the afternoon time block in Miesso (8.87± 0.16) during the dry season. Resting peaked during the midday time block in Seba (3.12± 0.44) during the wet season and it was higher in Menjiko (3.5±0.53) during the dry season. Walking was superior in the afternoon time block in

Lemana(2.75 ± 0.64) during the wet season and it was maximum in Seba (3.62±1.2) during the dry season. Vigilance was also more in the afternoon time block in Seba (2.62±0.46) during the wet season and it was greater in Miesso (2.87±0.55) during the dry season. Salt licking peaked during the wet season in Miesso (1.87±0.83) and it was higher during the dry season in Lemana (2.12±0.58) in the afternoon time block. Adult male warthog wallowing activity was higher during the wet season in Seba (1.75±0.72) and it was more during the dry season in Menjiko (2.12±0.45) in the afternoon time block (Table 22).

Adult male common warthog feeding ($\chi 2 = 1.12$, df = 1, P = 0.05) and resting ($\chi 2 = 4$, df = 1, P = 0.05) activities were not influenced by season. In contrast, walking ($\chi 2 = 6.4$, df = 1, P = 0.05), vigilance ($\chi 2 = 5.87$, df = 1, P = 0.05), salt licking ($\chi 2 = 5.67$, df = 1, P = 0.05) and wallowing ($\chi 2 = 14.28$, df = 1, P = 0.05) were influenced by season. All of these diurnal activities were more during the dry season than during the wet season (Table 17). There were significant difference among diurnal activities ($F_{5\ 66} = 87.6$, $P > 0.05$) during the wet and ($F_{5\ 66} = 80.3$, $P > 0.05$) during the dry seasons in the mean duration time of AF common warthog involved in behavioral activities. Tukey test realized a significant difference ($P < 0.05$) whenfeeding was compared with other behavioral activities during the wet and dry seasons. But, it did not show significant variations ($P>0.05$) between the remaining all multiple comparisons of the AM common warthog in GCHA (Table22).

Table 22. Diurnal behavioral activity patterns of mean ±SE of adult male common warthog in GCHA (w= wet season, d= dry season)

Study site	Season	Time block	Behavioral activities (in minutes)					
			Feeding	Resting	Walking	Vigilance	Salt licking	Wallowing
	w	7:00–10:00	7.75±0.35	0.25±0.25	1.87±0.23	1.25±0.16	1.12±0.74	0.37±0.37
		12:00–8:00	4.75±0.92	3±0.46	2±0.27	1.5±0.27	0.87±0.58	0
		3:00–6:00	8.5±0.26	1.62±0.37	2.5±0.33	2.12±0.35	1.87±0.83	0.62±0.65
Miesso	d	7:00–10:00	8.37±0.27	0.62±0.62	2.25±0.49	2.37±0.32	1.75±0.7	0.62±0.42
		12:00–8:00	4.37±0.88	2.87±0.55	2.87±0.44	2.5±0.59	1.25±0.67	0.75±0.53
		3:00–6:00	8.87±0.52	1.87±0.48	2.75±0.59	2.87±0.55	1.5±0.53	0.75±0.75
	w	7:00–10:00	8.8±0.29	0.62±0.42	2.12±0.23	1.37±0.32	0.62±0.37	1±0.68
		12:00–8:00	4.75±0.7	3.12±0.44	1.625±0.26	2±0.37	1.37±0.65	1.5±0.65
Seba		3:00–6:00	8.12±0.39	1.5±0.76	2.6±0.59	2.62±0.46	1.25±0.72	1.75±0.72
	d	7:00–10:00	8.7±0.41	1±0.68	2.37±0.53	2.62±0.78	1.25±0.65	1.62±0.65
		12:00–8:00	5±0.46	3±0.46	1.75±0.45	2.25±0.75	1.75±0.77	1±0.68
		3:00–6:00	8.25±0.45	1.37±0.59	3.62±1.2	2.5±0.73	1.37±0.65	1.87±1.1
	w	7:00–10:00	8.5± 0.38	1±0.65	1.5±0.27	1.12±0.29	0.5±0.38	0.75±0.5
		12:00–8:00	5.75±0.59	2.37±0.42	1.25±0.25	1±0.33	1.5±0.7	1.62±0.53
Lemana		3:00–6:00	8.12±0.48	2.5±0.73	2.75±0.64	2.5±0.65	0.75±0.25	0.87±0.39
	d	7:00–10:00	8.75±0.16	0.75±0.49	2.87±0.69	1.75±0.67	0.87±0.63	1.25±0.49
		12:00–8:00	5.5±0.98	2.5±0.32	2.25±0.55	2.12±0.72	1.87±0.74	1.5±0.7
		3:00–6:00	8.62±0.32	2.75±0.7	2.87±0.67	2.37±0.65	2.12±0.58	1.87±0.69
	w	7:00–10:00	8.75±0.5	0.75±0.16	1.87±0.4	1.5±0.38	1.37±0.73	0.75±0.31
		12:00–8:00	5.25±0.62	2.37±0.68	2±0.62	1.75±0.31	1.12±0.51	0.62±0.42
Menjiko		3:00–6:00	9±0.36	2.25±0.72	1.75±0.31	2.37±0.53	1.75±0.67	1.25±0.56
	d	7:00–10:00	8.25±0.45	1±0.19	2.5±0.5	2.37±0.46	1.62±0.65	1.12±0.48
		12:00–8:00	5.62±0.56	3.5±0.53	1.75±0.41	2.12±0.48	1.75±0.45	1.75±0.45
		3:00–6:00	8±0.42	1.62±0.53	3.27±0.53	2.75±0.62	2. ±0.45	2.12±0.45

In GCHA, the mean duration oftime AF spent for feeding was 7.62±0.48,for resting was 2.2±0.34, for salt licking was 1.17±0.12 and for wallowing was 1.11±0.17. The mean duration of time AMallocated for feeding was 7.37±0.49, for resting was 1.8±0.28, for salt licking was 1.09±0.14 and for wallowing was 0.92±0.15 during the wet season. They did not show significant difference in feeding ($F_{1\ 22} = 0.13$, $P > 0.05$), resting ($F_{1\ 22} = 0.13$, $P > 0.05$), salt

licking ($F_{1\ 22} = 0.13$, $P > 0.05$), and in wallowing ($F_{1\ 22} = 0.13$, $P > 0.05$) between AF and AM. However, the mean time AM engaged in walking (1.98±0.13) and vigilance (1.75±0.16) were higher than AF involved in walking (1.3±0.11) and vigilance (0.94±0.1). Hence, they showed significant variation in walking ($F_{1\ 22} = 15.9$, $P < 0.05$) and in vigilance ($F_{1\ 22} = 19.64$, $P < 0.05$) between AM and AF during the wet season in GCHA (Fig. 31). Morning time block= 07:00-10:00, Mid-day time block= 12: 00- 08:00, Afternoon time block= 09:00-6:00

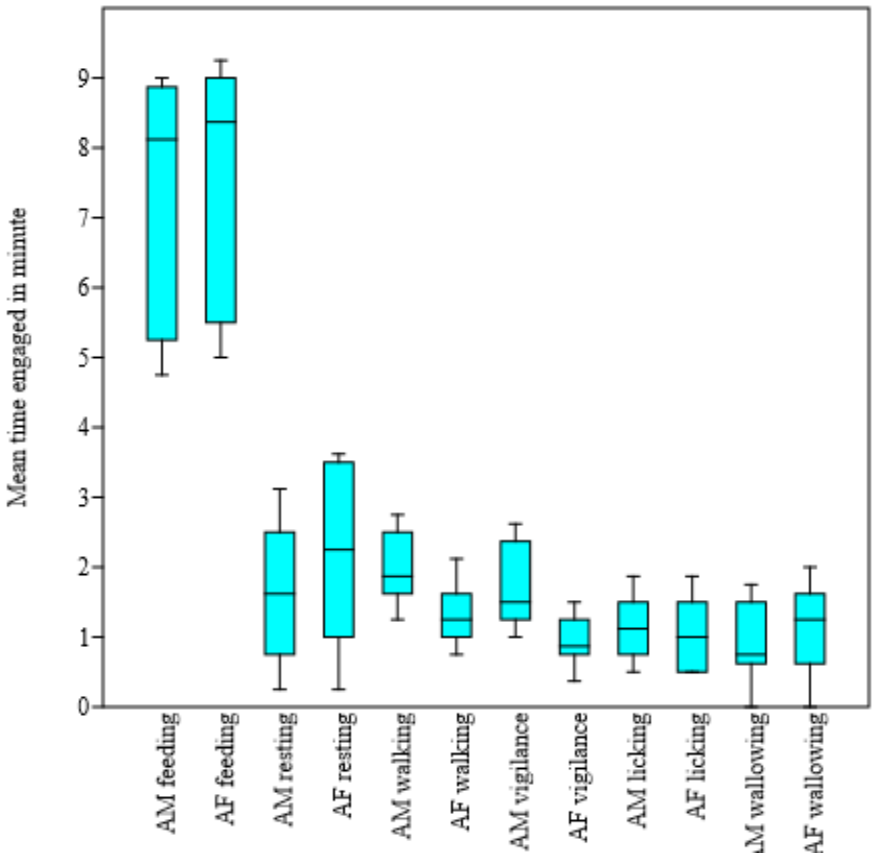


Figure31. Behavioral activity patterns of Adult male (AM) andAdultfemale (AF) common warthogs in GCHA during the wet season

During the dry season, the mean duration time AF engaged in feeding was 7.7±0.49, resting was 2.4±0.33, walking was2.34±0.1,salt licking was1.59±0.1 and in wallowing was1.38±0.11. Similarly, the mean duration of time AM spent for feeding was 7.33±0.48, in resting was 1.86±0.27, in walking was 2.6±0.16 andfor salt licking was 1.44±0.11 and for wallowing was 1.35±0.15 in GCHA. Therefore, they were insignificantly different in feeding ($F_{1\ 22} = 0.17$, $P > 0.05$), resting ($F_{1\ 22} = 1.59$, $P > 0.05$), walking ($F_{1\ 22} = 1.2$, $P > 0.05$), salt licking ($F_{1\ 22} = 0.85$, $P > 0.05$) and in wallowing ($F_{1\ 22} = 0.27$, $P > 0.05$) between AF and AM. However, the mean time AM engaged vigilance (2.38±0.87) was higher than AF involved (1.99±0.86) in the same behavioral activity. Hence, they showed significant variations($F_{1\ 22} = 9.8$, $P < 0.05$) between AM and AF during the dry season in GCHA (Fig. 32). Morning time block= 07:00- 10:00, Mid-day time block= 12: 00- 08:00, Afternoon time block= 09:00-6:00

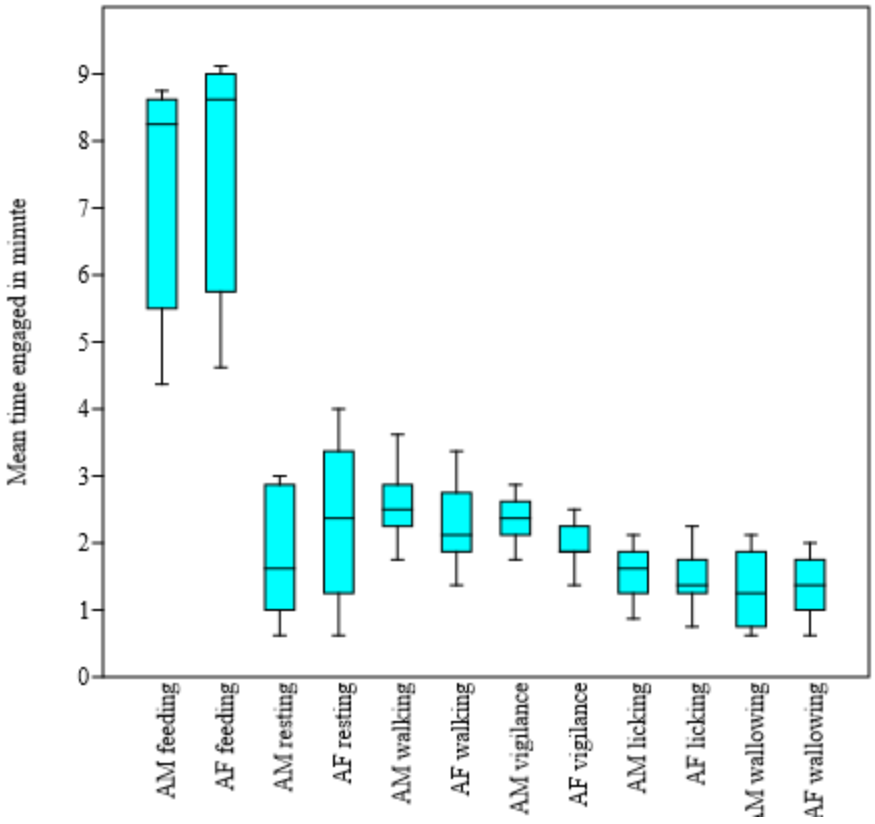


Figure 32. Behavioral activity patterns of Adult male (AM) and Adult female (AF) common warthogs in GCHA during the dry season

In HADCHA, the mean time AF common warthogs engaged in feeding peaked during the morning time block in Dodeta (9.75±0.25) during the wet season and it was higher in Desa (9.37± 0.37) during the dry season. Resting was elevated during the midday time block in Desa (4.12± 0.97) during the wet season and it peaked in Dodeta (5.37±0.7) during the dry season. Walking was higher in the afternoon time block in Robe (2.12 ± 0.55) during the wet season and

it was maximum in Gimbicho (2.37±0.59) during the dry season. Vigilance was higher in the afternoon time block in Desa (1.37±0.42) during the wet season and it was higher in Gimbicho (2.37±0.59) during dry season. Salt licking was more in the afternoon time block in Robe (2.37±0.7) during the wet season and it was higher in Desa (2.6±0.56) during the dry season. Wallowing of AF was more in Dodeta (2.5±0.53) during the wet season and it was higher in Gimbicho (2.87±0.64) during the dry season in the afternoon time blocks(Table 23).

Table 23. Diurnal behavioral activity pattern of of Adult female (AF) common warthog in HADCH Amean ±SE (w= wet season, d= dry season)

Study site	Season	Time block	Behavioral activities (in minutes)					
			Feeding	Resting	Walking	Vigilance	Salt licking	Wallowing
	W	7:00–10:00	8.87±0.23	0.87±0.64	1.25±0.36	0.5±0.26	1.5±0.7	0
		12:00–8:00	5.75±0.88	3.25±0.36	1.62±0.42	0.87±0.29	0.75±0.41	0
		3:00–6:00	8.62±0.46	3.62±1.1	2.12±0.55	1.12±0.39	2.37±0.7	1.25±0.72
Robe	D	7:00–10:00	9.25±0.313	1.12±0.58	1.62±0.56	1±0.57	1.87±0.85	0.37±0.26
		12:00–8:00	6.25±0.99	4.37±0.73	1.37±0.53	1.37±0.46	1.62±0.88	1±0.63
		3:00–6:00	9.12±0.03	4.25±0.97	2.25±0.45	1.62±0.49	2.12±0.83	1.37±0.65
	W	7:00–10:00	9.37±0.18	0.75±0.31	1.25±0.45	0.62±0.37	0.87±0.39	1±0.42
		12:00–8:00	5.87±0.83	4.12±0.76	0.75±0.31	0.87±0.39	1.25±0.41	1.37±0.53
Desa		3:00–6:00	8.87±0.29	2.87±0.51	1.75±0.49	1.37±0.42	1.37±0.7	1.87±0.69
	D	7:00–10:00	9.37±0.37	1.25±0.6	2±0.68	1.12±0.67	1.37±0.65	1.37±0.65
		12:00–8:00	6.37±0.7	4.37±0.75	1.25±0.56	1.37±0.59	1.75±0.65	1.5±0.7
		3:00–6:00	8.75±0.45	3.75±0.94	2.25±0.75	1.5±0.57	2.6±0.56	2.37±1.1
	W	7:00–10:00	9±0.42	0.75±0.31	1.5±0.26	0.87±0.12	1±0.42	1.12±0.35
		12:00–8:00	9±0.42	0.75±0.31	1.5±0.26	0.87±0.12	1±0.42	1.12±0.35
Gimbicho		3:00–6:00	9.12±0.39	2.75±0.91	1.87±0.39	1.12 0.61	1.75±0.31	2±0.5
	D	7:00–10:00	9.25±0.41	1.25±0.56	2.12±0.39	1.12±0.22	1.62±0.37	1.25±0.16
		12:00–8:00	6.62±1.13	4.62±1.01	1.87±0.51	1.5±0.5	2.12±0.4	1.87±0.35
		3:00–6:00	9±0.42	3.12±0.51	2.37±0.59	2±0.42	1.37±0.37	2.87±0.64
	W	7:00–10:00	9.75±0.25	1.12±0.23	1±0.26	1.25±0.31	1.37±0.59	1.12±0.22
		12:00–8:00	6.75±0.52	3.75±0.77	1±0.19	1.12±0.29	1.62±0.56	1.37±0.32
Dodeta		3:00–6:00	9±0.32	2.12±0.58	1.5±0.27	1.25±0.31	1.12±0.35	2.5±0.53
	D	7:00–10:00	9.25±0.25	1.75±0.52	1.62±0.26	1.62±0.26	1.750.56	1.25±0.16
		12:00–8:00	6.87±0.76	5.37±0.7	1.370.18	1.75±0.25	2±0.32	1.87±0.4
		3:00–6:00	9.12±0.35	2.62±0.78	2±0.46	1.87±0.51	2.37±0.42	2.12±0.69

Feeding ($\chi 2 = 0.59$, df = 1, P = 0.05), resting ($\chi 2 = 2.21$, df = 1, P = 0.05), walking ($\chi 2 = 2.31$, df = 1, P = 0.05) and vigilance activities ($\chi 2 = 0.7$, df = 1, P = 0.05) of AF warthogs were not influenced by season. In contrast, salt licking ($\chi 2 = 5.04$, df = 1, P = 0.05), and wallowing ($\chi 2 = 10.83$, df = 1, P = 0.05) were influenced by season. These diurnal activitiesmore during the dry season than during wet season (Table 18). Moreover, there were significant differences among diurnal activities ($F_{5\ 66} = 113$, $P > 0.05$) during the wet ($F_{5\ 66} = 104$, $P > 0.05$) and during the dry seasons in the mean duration time of AF common warthogs. Tukey test confirmed a significance differences ($P < 0.05$) when feeding was compared with other behavioral activities during the wet and dry seasons in HADCHA (Table 23).

The meanduration oftime AM common warthog involved in feeding was higher in the morning time block in Dodeta (9.37±0.42) during the wet season. This was more in Gimbicho (9.12± 0.39) during the dry season. Resting peaked during the midday time block in Desa (3.87± 0.85) during the wet season and it was higher in Dodeta (4.87±0.72) during the dry season. Walking peaked in the afternoon time block in Robe (2.75 ± 0.52) during the wet season and it was maximum in Desa (2.62±0.53) during the dry season. Vigilance was also climax in the afternoon time block in Gimbicho (2±0.38) during the wet season and it was greater in Robe (2.25±0.49) during the dry season. Salt licking was maximum in the afternoon time block in Gimbicho (2.12±0.32) during the wet season and it was higher in Desa (2.37±0.59) during the dry season. Wallowing activity of AF warthogs more in the afternoon time block in Dodeta (2.25±0.049) during the wet season and it higher in Gimbicho (2.5±0.57) during the dry season (Table 24).

Table 24. Diurnal behavioral activity pattern of of Adult male (AM) common warthog in HADCHA mean ±SE (w= wet season, d= dry season)

Study site	Season	Time block	Behavioral activities (in minutes)					
			Feeding	Resting	Walking	Vigilance	Salt licking	Wallowing
	w	7:00–10:00	8.37±0.65	0.75±0.52	1.75±0.31	1.12±0.35	1.37±0.59	0
		12:00–8:00	5.25±1	2.87±0.39	2±0.38	1.37±0.18	0.62±0.26	0
		3:00–6:00	8.25±0.45	2.62±0.88	2.75±0.52	1.75±0.31	2±0.67	1.25±0.62
Robe	d	7:00–10:00	9±0.27	0.87±0.4	1.87±0.48	1.37±0.49	1.62±0.75	0.37±0.26
		12:00–8:00	5.87±0.85	3.75±0.52	1.75±0.41	1.62±0.37	1.25±0.67	0.75±0.41
		3:00–6:00	8.87±0.35	3.5±0.91	2.15±0.49	2.25±0.49	1.75±0.06	1.25±0.55
	w	7:00–10:00	8.75±0.43	0.62±0.37	1.87±0.48	1.25±0.31	0.87±0.39	0.75±0.36
		12:00–8:00	5.37±0.7	3.87±0.85	1.75±0.25	1.37±0.26	1.12±0.48	1.25±0.45
Desa		3:00–6:00	8.5±0.46	2.37±0.49	2.37±0.53	1.87±0.54	1.37 0.65	1.75±0.7
	d	7:00–10:00	9±0.46	1.12±0.48	2±0.62	1.5±0.59	1.12±0.55	1.25±0.6
		12:00–8:00	6.12±1	4±0.57	1.62±0.46	1.75±0.49	1.62±0.56	1.37±0.59
		3:00–6:00	8.5±0.38	3.5±0.82	2.62±0.65	1.870.39	2.37±0.59	2.2±1.04
	w	7:00–10:00	8.75±0.36	0.62±0.42	2.25±0.56	1.37±0.26	0.87±0.29	1±0.26
		12:00–8:00	6±0.71	3.12±0.67	1.75±0.49	1.75±0.41	1.12±	1.5±0.27
Gimbicho		3:00–6:00	8.75±0.45	2.25±0.59	2.37±0.56	2±0.42	1.25±0.52	1.87±0.39
	d	7:00–10:00	9.12±0.39	1.12±0.48	2.37±0.53	1.5±0.27	1.62±0.26	1.250.16
		12:00–8:00	6.12±1	4.37±0.96	2±0.5	1.87±0.39	1.12±0.29	1.75±0.25
		3:00–6:00	8.62±0.46	3±0.463	2.5±0.5	1.75±0.49	2.12±0.32	2.5±0.57
	w	7:00–10:00	9.37±0.42	1±0.33	1.62±0.26	1.37±0.26	1.12±0.4	1±0.19
		12:00–8:00	6.25±0.52	3.25±0.84	1.75±0.41	1.62±0.26	1±0.33	1.25±0.25
Dodeta		3:00–6:00	8.62±0.32	2±0.73	2.25±0.56	1.87±0.51	1.12±0.35	2.25±0.49
	d	7:00–10:00	9±0.19	1.37±0.37	1.87±0.29	2±0.38	1.37±0.32	1.25±0.16
		12:00–8:00	6.62±0.65	3.75±0.45	1.75±0.25	1.87±0.48	1.62±0.32	1.37±0.32
		3:00–6:00	8.75±0.31	4.87±0.72	2±0.38	2.12±0.35	1.87±0.22	1.75±0.45

Feeding activity ($\chi2 = 0.26$, df = 1, P = 0.05) resting ($\chi2 = 2.24$, df = 1, P = 0.05), walking ($\chi2 = 0.54$, df = 1, P = 0.05), vigilance ($\chi2 = 1.11$, df = 1, P = 0.05) and salt licking activities ($\chi2 = 3.14$, df = 1, P = 0.05) of AM warthogs were not influenced by season. In contrast, wallowing ($\chi2 = 11.41$, df = 1, P = 0.05) was influenced by season and AM common warthog spent more time during the dry season than wet season for wallowing (Table 24). There were a significant

differences among diurnal activities during the wet ($F_{5\ 66} = 105.5$, $P > 0.05$) and the dry seasons ($F_{5\ 66} = 87.8$, $P > 0.05$) in the mean duration time AM engaged in these behavioral actions.Tukey test realized a significant difference ($P < 0.05$) when feeding was compared with others behavioral activities during the wet and dry seasons in HADCHA (Table 24).

The mean time used by AF feeding was 8.33±0.39 and 7.68±0.43 byAM, for resting, 2.23±0.38 in AF and 2.11±0.32 in AM, for salt licking 1.33±0.12in AF and 1.15±0.1 in AM, and for wallowing 1.22±0.2 in AF and 1.15±0.1 in AM during the wet season in HADCHA. Therewas no significant differencein feeding ($F_{1\ 22} = 1.2$, $P > 0.05$), resting ($F_{1\ 22} = 0.5$, $P > 0.05$), salt licking ($F_{1\ 22} = 1.14$, $P > 0.05$), and in wallowing ($F_{1\ 22} = 0.6$, $P > 0.05$) between AF and AM. However, the mean time AM spent for walking (2.04±0.1) and vigilance (1.52±0.16) were higher than that of AF for walking (1.42±0.11) and vigilance (0.98±0.1). Hence, they revealed significant variation in walking ($F_{1\ 22} = 16.2$, $P < 0.05$) and in vigilance ($F_{1\ 22} = 23.5$, $P < 0.05$) during the wet season in HADCHA (Fig.33). Morning time block= 07:00- 10:00, Mid-day time block= 12: 00- 08:00, Afternoon time block= 09:00-6:00

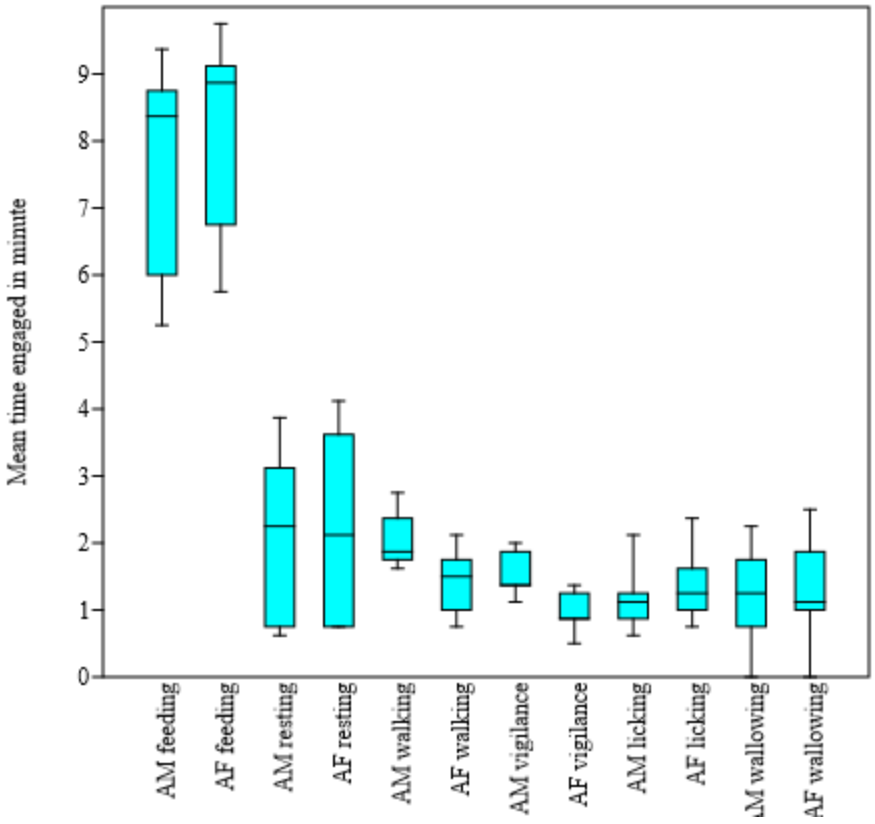


Figure33. Behavioral activity patterns of Adult male (AM) and Adult female (AF) common warthogs in HADCHAduring the wet season

During the dry season, the mean duration oftime AFengaged in feeding was 8.26±0.37, in resting was 3.15±0.33, in walking was 1.84±0.11, in salt licking was1.88±0.1 and in wallowing was 1.6±0.19. Similarly,the mean duration time AMallocated for feeding was 7.96±0.38,for resting was 2.93±0.4, for walking was 2.09±0.1, for salt licking was 1.61±0.1 and for wallowing was 1.42±0.16 in HADCHA. Therefore, they showed insignificant difference in feeding ($F_{1\ 22} = 0.31$, $P > 0.05$), resting ($F_{1\ 22} = 0.13$, $P > 0.05$), walking ($F_{1\ 22} = 2.62$, $P > 0.05$), salt licking ($F_{1\ 22} =$

3.12, P > 0.05) and wallowing ($F_{1\ 22} = 0.42$, P > 0.05) between AF and AM. However, the mean duration oftime AM spent for vigilance (1.79±0.07) was higher than that of AF (1.48±0.08). Hence, they showed significant variation ($F_{1\ 22} = 6.67$, P < 0.05) between AM and AF during the dry season in HADCHA (Fig. 34). Morning time block= 07:00- 10:00, Mid-day time block= 12: 00- 08:00, Afternoon time block= 09:00-6:00

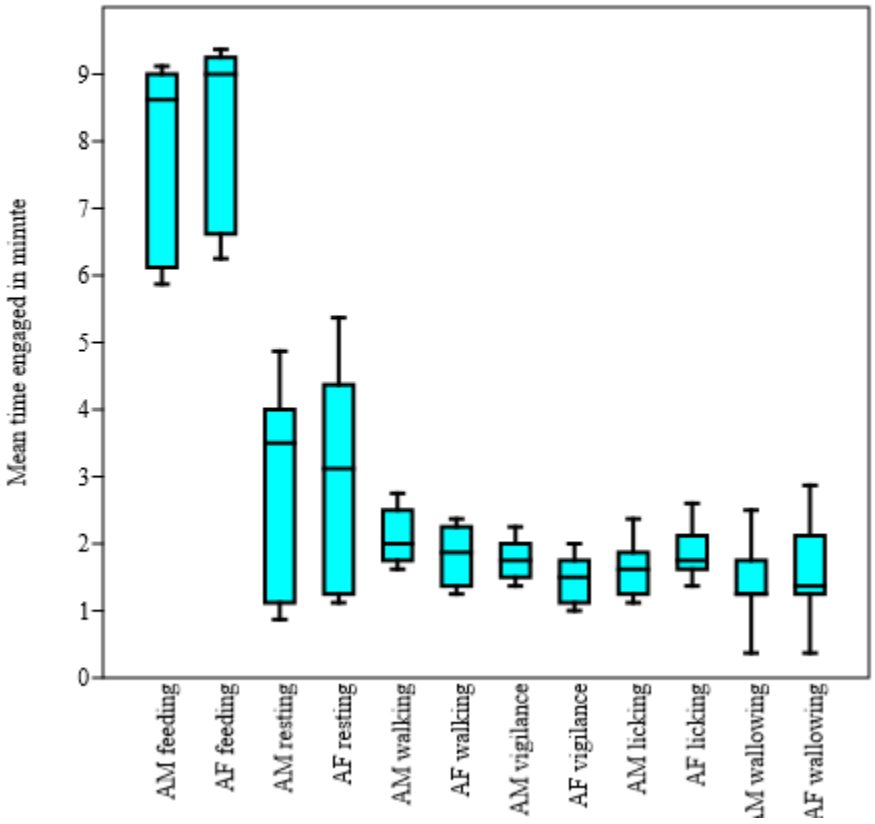


Figure 34. Behavioral activity patterns of Adult male (AM) and Adult female (AF) common warthogs in HADCHAduring the dry season

The mean durationof time Adult female (AF) spent in feeding was 7.62±0.48 in GCHA and 8.33±0.37 in HADCHA. Resting was 2.21±0.34 in GCHA and 2.23±0.38 in HADCHA, walking was 1.3±0.11 in GCHA and 1.42±0.12 in HADCHA during the wet season. On the other hand, the mean time AF engaged, in vigilance was 0.94±0.16 in GCHA and 0.98±0.1 in HADCHA, salt licking was 1.09±0.12 in GCHA and 1.33±0.12 in HADCHA, and wallowing was 1.12±0.17 in GCHA and 1.23±0.2 in HADCHA during the wet season (Table 25). Therefore, there were no significant variations ($P > 0.05$) when AF engagedin feeding, in resting, in walking, in vigilance, in salt licking and in wallowing between the study areas during wet season (Table 25)

Table 25. Behavioral activities of Adult female (AF) warthogs in GCHA and HADCHA during the wet and dry seasons

Behavioral activities	GCHA		HADCHA	
	Wet	Dry	Wet	Dry
Feeding	7.62±0.48	7.7±0.49	8.33±0.37	8.27±0.32
Resting	2.21±0.34	2.4±0.33	2.23±0.38	3.15±0.33
Walking	1.3±0.11	2.34±0.17	1.42±0.12	1.84±0.08
Vigilance	0.94±0.16	1.99±0.86	0.98±0.1	1.48±0.08
Salt licking	1.09±0.12	1.44±0.1	1.33±0.12	1.88±0.2
Wallowing	1.12±0.17	1.38±0.11	1.23±0.2	1.6±0.19

The mean duration of time AF engaged in feeding was 7.7±0.49 in GCHA and 8.27±0.32 in HADCHA. Resting was 2.4±0.33 in GCHA and 3.15±0.33 in HADCHA and, wallowing was 1.38±0.11 in GCHA and 1.6±0.19 in HADCHA during the dry season. On the other hand, AF

attained more mean duration time in walking 2.34±0.17 and in vigilance 1.84±0.08in GCHA than in walking (1.84±0.08) and in vigilance (1.48±0.08) in HADCHA. Salt licking was higher in HADCHA (1.88±0.2) than in GCHA (1.44±0.1) during the dry season (Table 25). Therefore, there were no significant variations ($P > 0.05$) whenAF engaged in feeding, in resting and in wallowing between GCHA and HADCHA. In contrast, there were significant variation in walking ($F_{1\ 22} = 6$, $P < 0.05$), in vigilance ($F_{1\ 22} = 16.99$, $P < 0.05$) and in salt licking ($F_{1\ 22} = 7.24$, $P < 0.05$) between the two study areas.

The mean duration of time Adult male (AM) allocated for feeding was 7.37±0.49 in GCHA and 7.68±0.43 in HADCHA during the wet season. Resting was 1.8±0.28 in GCHA and 2.11±0.32 in HADCHA, walking was 1.98±0.13 in GCHA and 2.04±0.1 in HADCHA. Similarly, vigilance was 1.75±0.16 in GCHA and 1.52±0.08 in HADCHA, salt licking was 1.09±0.14 in GCHA and 1.15±0.1 in HADCHA, and wallowing was 0.92±0.15 in GCHA and 1.16±0.19 in HADCHA during the wet season (Table 26). Hence,there were no significant variations ($P > 0.05$) when AM engaged inall behavioral activities between GCHA and HADCHA during the wet season.

During the dry season, the mean duration of time AM spent in feeding was 7.33±0.48 in GCHA and 7.96±0.38 in HADCHA. Resting was 1.86±0.27 in GCHA and 2.93±0.4 in HADCHA, wallowing was 1.35±0.15 in GCHA and 1.42±0.16 in HADCHA, and salt licking was 1.44±0.11 in GCHA and 1.61±0.1 in HADCHA. On the other hand, AM attained more mean duration time in walking (2.6±0.16) and in vigilance (2.38±0.87) in GCHA than engaged walking (2.09±0.1) and vigilance (1.79±0.07) in HADCHA. Therefore, there were no significant variation ($P > 0.05$)

inAM engaged in feeding in resting, in wallowing, and in salt licking. However, there were a significant difference in walking ($F_{1\ 22} = 6.65$, $P < 0.05$) and in vigilance ($F_{1\ 22} = 26.21$, $P < 0.05$) between GCHA and HADCHA (Table 26).

Table 26. Behavioral activities of Adult male (AM) warthogs in GCHA and HADCHA during the wet and dry seasons

Behavioral activities	GCHA		HADCHA	
	Wet	Dry	Wet	Dry
Feeding	7.37±0.49	7.33±0.48	7.68±0.43	7.96±0.38
Resting	1.8±0.28	1.86±0.27	2.11±0.32	2.93±0.4
Walking	1.98±0.13	2.6±0.16	2.04±0.1	2.09±0.1
Vigilance	1.75±0.16	2.38±0.87	1.52±0.08	1.79±0.07
Salt licking	1.0.9±0.14	1.44±0.11	1.15±0.1	1.61±0.1
Wallowing	0.92±0.15	1.35±0.15	1.16±0.19	1.42±0.16

Adult common warthogs spent the highest proportion of the daytimein feeding (47.21%), followed by resting (14.29%) and walking (11.94%). Less frequency behavioral activities were in salt licking (8.65%) and wallowing (7.89%) in GCHA and HADCHA during wet and dry seasons. Thus, there were significant differences($\chi 2 = 18.91$, df = 5, $P = 0.05$) in the proportion of time among diurnal activities in both the study areas (Table 27).

Table 27. Proportion of behavioral activities engaged by Adult female (AF) and Adult male (AM) common warthogs in GCHA and HADCHA during the wet and dry seasons

Activity	GCHA		HADCHA		Total
	%AF	%AM	%AF	%AM	
Feeding	11.73	11.23	12.52	11.73	47.21
Resting	3.49	2.8	4.31	3.69	14.29
Walking	2.77	3.52	2.48	3.17	11.94
Vigilance	2.24	3.18	1.91	2.55	9.88
Salt licking	1.94	2.11	2.48	2.12	8.65
Wallowing	1.91	1.8	2.19	1.99	7.89
Total					99.86

6.4. Feeding ecology

From the leaf cuticle fragments observation of feces, forty–one plant species were recognized as annual dietary components of common warthog in GCHA. Out of these plant species, 32 were recorded during the wet and 29 were during the dry season. Among these20 plant species were common in both the wet and dry seasons (Appendix VI). Graminoids accounted as the largest forage species (25), followed by herbs (11). Shrubs (3) and climbers (2) the least foraged species (Fig. 35). The amount of forage species consumed by common warthogs among the four forage categories showed a significant difference ($\chi 2 = 26.03$, df = 3, P = 0.05), but there was no considerable seasonal variation ($\chi 2 = 1.16$, df=1, P >0.05), among the four forage categories in GCHA.

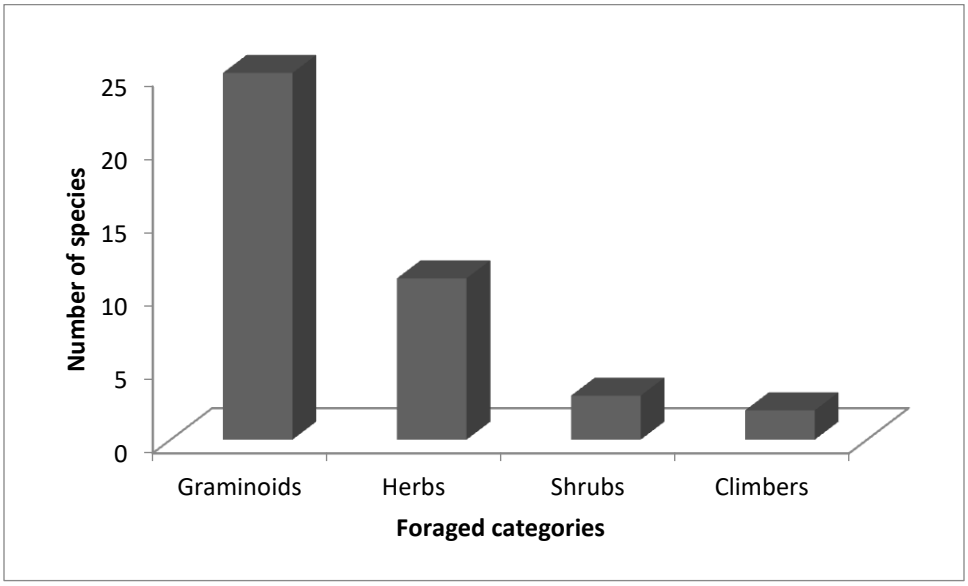


Figure 35. Forage categories and number of plant species identified as dietary components of common warthogs in GCHA

From HADCHA, forty-five plant species were identified as annual dietary component of warthogs. Of these foraged species, 35 were documented during the wet and 30 species during the dry season.Among these, 20 species were common to both seasons (Appendix VII). In this study area also, graminoids accounted for the largest identified forage category (27) followed, by herbs (12). Shrubs (4) and climbers (2) were the least foraged species (Fig. 36). The amount of forage species consumed by common warthog showed a significant difference ($\chi 2 = 11.49$, df = 3, P = 0.05) among the four forage categories. However, they revealed insignificant variation ($\chi 2 = 1.92$, df=1, P >0.05) between the two seasons. On the other hand, the two study areas were not significantly different ($\chi 2 = 0.34$, df=1, P >0.05) in the number of forage species consumed by common warthog population.

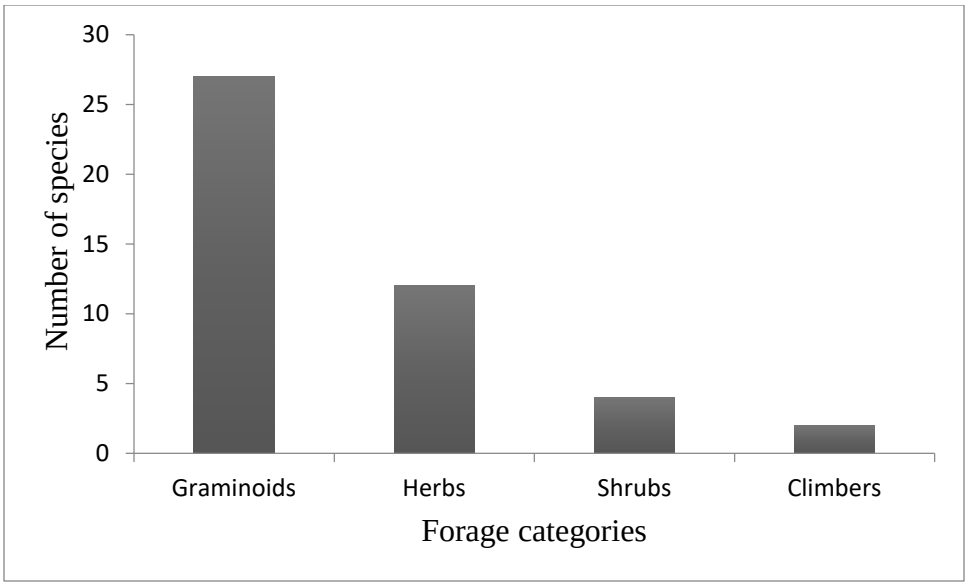


Figure 36. Forage categories and number of plant species identified as dietary components of common warthogs in HADCHA

Uncertainty of epidermal fragments and fine digestion,led certain forage species consumed by common warthog to be unidentified. Beyond the identified graminoids, herbs, shrubs and climbers, the fecal analysis showed unidentified graminoids, dicots, seeds and other fragments (Table 28). In GCHA, *Cynodon nlemfuensis* (75.5), *Cynodon dactylon* (69), *Cyperus fischerianus* (47),*Digitaria abyssinica* (46.5) and *Andropogon abyssinicus* (46.5) had the higher relative frequency occurrence (RFO) in the feces of the animal during the wet season. *Cynodon nlemfuensis* (82.5), *Cynodon dactylon* (71.5) *Andropogon abyssinicus* (45.5), *Hyparrhenia rufa* (45.5) and *Borassusa ethiopum* (26) were the top five frequently observed species in the feces of warthogs during the dry season. *Melinis repen* (2) and *Cordia africana* (3) showed the least relative frequency occurrence (RFO) during the wet and dry seasons, respectively. In this study area,unidentified graminoids (W=34.5, D= 50.5) and unknown fragments (W=26, D=24.5) accounted for the largest RFO during both seasons. Unidentified seeds (W=2.5, D= 8) showed the least RFO in the feces during both seasons. In GCHA, there was no significant variation (F_3

$_{28}$= 1.482, P> 0.05) during the wet season and ($F_{1\ 25}$= 2.11, P > 0.05) the dry season in the RFO of foraged species(Table 28)

Table 28. Relative frequency occurrence (RFO) of epidermal fragments identified by microhistological analysis from 32 slides of fecal samples collected from GCHA during the wet and dry seasons (T.F= Total Field)

		Wet			Dry		
Family	Species	T. F	RFO	%	T. F	RFO	%
	Graminoids=25						
Cyperaceae	*Cyperus fischerianus*	115	47.5	6.48	67	20.5	2.89
Cyperaceae	*Cyperus distans*	33	8.5	1.15	32	7	0.99
Cyperaceae	*Cyperus papyrus*	29	6.5	0.88	26	6	0.84
Cyperaceae	*Cyperus longus*	21	5	0.68	27	5.5	0.77
Poaceae	*Digitaria ciliaris*	36	7	0.95	28	6	0.845
Poaceae	*Digitaria abyssinica*	114	46.5	6.34	75	24	3.39
Poaceae	*Eragrostis tef*	0	0	0	86	25.5	3.6
Poaceae	*Zea mays*	0	0	0	60	17	2.41
Poaceae	*Sorghum bicolor*	0	0	0	62	18.5	2.61
Poaceae	*Eleusine coracana*	0	0	0	67	19	2.68
Poaceae	*Triticum aestivum*	0	0	0	38	6	0.84
Poaceae	*Cynodon dactylon*	267	71.5	9.75	251	69	9.75
Poaceae	*Cynodon nlemfuensis*	309	82.5	11.25	297	75.5	10.67
Poaceae	*Hyparrhenia rufa*	124	47	6.41	109	45.5	6.43
Poaceae	*Hyparrhenia anthistirioides*	55	19	2.59	48	15.5	2.19
Poaceae	*Hyparrhenia hirta*	72	24.5	3.34	102	42	5.94
Poaceae	*Hyparrhenia varibilis*	51	17	2.31	44	24.5	3.46
Poaceae	*Panicum maximum*	57	17.5	2.38	69	21	2.97
Poaceae	*Pennisctum nubicwn*	65	22	3	0	0	0
Poaceae	*Pennisetum clandestinum*	27	6.5	0.88	41	7.5	1.06
Poaceae	*Pennisetum purpureum*	31	7	0.95	0	0	0

Poaceae	*Melinis repen*	20	4	0.54	0	0	0
Poaceae	*Setaria poiretiana*	62	21.5	2.93	0	0	0
Poaceae	*Sporobolus festivus*	26	6.5	0.89	0	0	0
Poaceae	*Andropogon abyssinicus*	137	46.5	6.34	113	45.5	6.43
	Herbs= 11						
Arecaceae	*Borassusa ethiopum*	63	21.5	2.93	71	26	3.67
Boraginaceae	*Cordia africana*	0	0	0	8	3	0.42
Combretaceae	*Terminalia brownii*	16	6	0.81	0	0	0
Commelinaceae	*Commelina benghalensis*	55	18.5	2.52	0	0	0
Dracaenaceae	*Dracaena steudneri*	22	7	0.95	0	0	0
Fabaceae	*EntAMa abyssinica*	28	6	0.81	12	4	0.56
Fabaceae	*Sesbania sesban*	73	23	3.13	0	0	0
Moraceae	*Ficus sycomorus*	0	0	0	53	24.5	3.46
Moraceae	*Ficus sur* (*F. capensis*)	0	0	0	47	16	2.23
Moraceae	*Ficus vasta*	0	0	0	28	9.5	1.34
Salicaceae	*Salix mucronata*	28	8.5	1.15	29	10	1.41
	Shrbs=3						
Apiaceae	*Diplolophium africanum*	57	17	2.33	0	0	0
Brassicaceae	*Sisymbrium maximum*	17	5.5	0.75	0	0	0
Euphorbiaceae	*Tragia pungens*	17	4.5	0.61	14	6	0.84
	Climbers=2						
AsclepiAMaceae	*Pergularia daemia*	22	6.5	0.89	7	3.5	0.49
Menispermaceae	*Stephania abyssinica*	21	7	0.95	0	0	0
	Unidentified						
Unidentified	Graminoids	99	34.5	4.72	128	50.5	7.14
Unidentified	Dicots	50	21.5	2.94	49	20	2.82
Unidentified	Seeds	5	2.5	0.34	19	8	1.13
Unidentified	Fragments	57	26	3.56	54	24.5	3.46

In HADCHA, during the wet season,*C. nlemfuensis* (85), *C. dactylon* (77.5), *H. rufa* (53), *C. fischerianus* (46) and *A. abyssinicus* (26.5) had the higher RFO in the feces of common warthog population. Similarly, *C. nlemfuensis* (76.5), *C. dactylon* (73.5), *H. rufa* (57.5), *C. fischerianus* (45)and *A. abyssinicus* (25)were the top five forage species with higher RFO in the feces of the warthog during the dry season (Table 29). *Sisymbrium maximum* (3.5) and *Tragia pungens* (3.5) showed the least RFO during the wet and dry seasons, respectively. In this study area unidentified graminoids (W=42, D= 40.5) and unknown fragments (W=28.5, D=25) accounted for the higherRFO in the feces of common warthogs during both seasons. In contrast, unidentified seeds (W=4.5, D= 9) showed the least RFO in the feces during both seasons. There were no significant differences ($F_{3\ 31}$= 1.53, P > 0.05), ($F_{1\ 25}$= 1.82, P > 0.05) in the RFO of foraged species during wet and dry seasons, respectively. The higher annual RFO of forage species of both study areas consisted of *C. nlemfuensis, C. dactylon* and *H. rufa*. However, therewas insignificant variation ($\chi 2$ = 0.558, df=2, P >0.05).

Table 29. Relative frequency occurrence (RFO) of epidermal fragments identified by microhistological analysis from 32 slides of fecal samples collected from HADCHA during the wet and dry seasons (T.F= Total Field)

		Wet			Dry		
Family	Species	T. F	RFO	%	T. F	RFO	%
	Graminoids=27						
Cyperaceae	*Cyperus fischerianus*	125	46	6.05	106	45	6.69
Cyperaceae	*Cyperus distans*	35	10	1.31	30	9.5	1.41
Cyperaceae	*Cyperus papyrus*	36	9	1.18	26	6.5	0.96
Cyperaceae	*Cyperus longus*	31	9.5	1.25	18	6	0.89
Poaceae	*Digitaria ciliaris*	39	14	1.84	27	7.5	1.11
Poaceae	*Digitaria abyssinica*	96	55	7.23	102	35	5.2
Poaceae	*Eragrostis tef*	0	0	0	93	30	4.46
Poaceae	*Zea mays*	0	0	0	40	13	1.93
Poaceae	*Sorghum bicolor*	0	0	0	65	20	2.97
Poaceae	*Eleusine coracana*	0	0	0	61	16	2.37
Poaceae	*Triticum aestivum*	0	0	0	12	4.5	0.66
Poaceae	*Cynodon dactylon*	296	77.5	10.1	239	73.5	10.9
Poaceae	*Cynodon nlemfuensis*	312	85	11.18	263	76.5	11.38
Poaceae	*Hyparrhenia rufa*	153	53	6.97	189	57.5	8.55
Poaceae	*Hyparrhenia anthistirioides*	67	22	2.89	48	13.5	2.01
Poaceae	*Hyparrhenia hirta*	68	21.5	2.82	72	25	3.72
Poaceae	*Hyparrhenia cymbaria*	51	14	1.84	43	12	1.78
Poaceae	*Hyparrhenia varibilis*	59	13	1.71	36	10	1.48
Poaceae	*Panicum maximum*	56	12.5	1.64	43	11.5	1.71
Poaceae	*Pennisctum nubicwn*	53	14.5	1.9	0	0	0
Poaceae	*Pennisetum clandestinum*	29	9	1.18	17	6	0.89
Poaceae	*Pennisetum purpureum*	16	4	0.52	0	0	0
Poaceae	*Melinis repen*	21	6	0.78	0	0	0
Poaceae	*Setaria poiretiana*	65	21	2.76	0	0	0
Poaceae	*Snowdenia polystachya*	19	6	0.78	0	0	0

Poaceae	*Sporobolus festivus*	17	6	0.78	0	0	0
Poaceae	*Andropogon abyssinicus*	77	26.5	3.48	74	25	3.72
	Herbs= 12						
Arecaceae	*Borassusa ethiopum*	50	15	1.97	72	22.5	3.34
Boraginaceae	*Cordia africana*	0	0	0	19	5.5	0.81
Combretaceae	*Terminalia brownii*	26	9	1.18	0	0	0
Commelinaceae	*Commelina benghalensis*	55	13.5	1.77	0	0	0
Dracaenaceae	*Dracaena steudneri*	21	7	0.92	0	0	0
Fabaceae	*EntAMa abyssinica*	14	6.5	0.85	0	0	0
Fabaceae	*Sesbania sesban*	61	22.5	2.96	0	0	0
Moraceae	*Ficus sycomorus*	0	0	0	35	10	1.48
Moraceae	*Ficus sur* (*F. capensis*)	0	0	0	28	9	1.33
Moraceae	*Ficus vasta*	0	0	0	26	10.5	1.56
Myrtaceae	*Syzygium guineense*	0	0	0	34	10.5	1.53
Salicaceae	*Salix mucronata*	16	6	0.78	38	12.5	1.86
	Shrubs = 4						
Apiaceae	*Diplolophium africanum*	49	14	1.84	0	0	0
Brassicaceae	*Sisymbrium maximum*	15	3.5	0.46	0	0	0
Euphorbiaceae	*Tragia pungens*	18	6	0.78	12	3.5	0.52
Malvaceae	*Hibiscus macranthus*	22	9.5	1.25	0	0	0
	Climbers= 2						
AsclepiAMaceae	*Pergularia daemia*	16	8	1.05	0	0	0
Menispermaceae	*Stephania abyssinica*	13	6.5	0.85	0	0	0
	Unidentified						
Unidentified	Graminoids	117	42	5.52	111	40.5	6.02
Unidentified	Dicots	59	23	3.02	45	20	2.97
Unidentified	Seeds	9	4.5	0.59	20	9	1.34
Unidentified	Fragments	48	28.5	3.75	42	25	3.72

In GCHA, common warthogs foraged almost the same proportion of graminoids during the dry season (77.4%±1.15) and the wet season (77%±1.16). More herbs were used during the wet

season (15%±0.62) than the during dry season (12.2%±0.69). Similarly, common warthog consumed both shrubs and climbers only during the wet season (Fig. 37). Seasonal contribution of forage categories to the diet of common warthog was not significantly different ($F_{1\ 7} = 0.008$, $P > 0.05$).In GCHA, the highest annual diet proportion of common warthog was covered by graminoids (77.2± 0.84) followed by herbs (13.6±0.64).

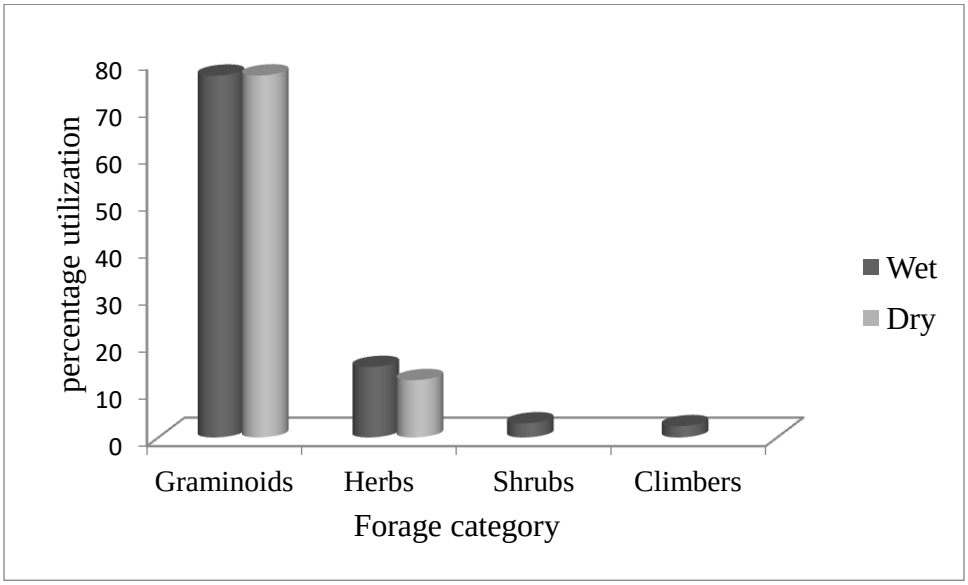


Figure 37. Seasonal dietary contribution (%) of forage categories of the diet of common warthogs in GCHA

In HADCHA, common warthogs consumed graminoids more during the wet season (79.6%±1.1) than during the dry season (77.08%±1.27). Herbs were used more during the dry season (13.6%±1.08) than during the wet season (10%±1.06). Both shrubs and climbers were consumed only during the wet season (Fig. 38). Seasonal contribution of forage categories of the diet of common warthog was not significantly different ($F_{1\ 7} = 0.22$, $P > 0.05$).The highest annual diet composition of common warthog was covered by graminoids (78.7± 0.91), followed by herbs (11.8±0.53). The annual contribution of forage categories to the diet of common warthog was not significantly different ($F_{1\ 7} = 0.009$, $P > 0.05$) between GCHA and HADCHA.

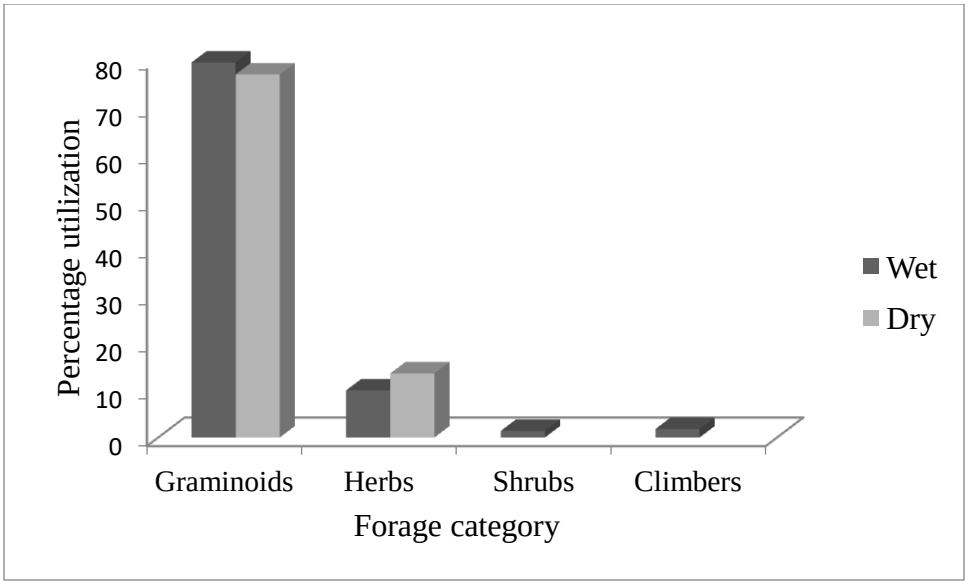


Figure 38. Seasonal dietary contributions (%) of different forage categories to the diet of common warthog in HADCHA

During the wet seasonin GCHA,*C. fischerianus, D. abyssinica, C. dactylon, C. nlemfuensis, H. rufa, A. abyssinicus, Sesbania sesban* and *Diplolophium africanum* were identified as the staple forage species of common warthogs. Of these, *S. sesban* and *D. africanum* were foraged during this season only. The eight staple forage species accounted 75.8% of the wet season diet of common warthogs. Out of these, the top three staple forage species*C. nlemfuensis* (23.4%), *C. dactylon* (15.2%), and *H. rufa* (9.6%) consistedfor 48.2% of the wet season diet (Table30). During the dry season *C. dactylon, C. nlemfuensis, Hyparrhenia rufa, Hyparrhenia hirta, A. abyssinicus,Borassusa ethiopum, Eragrostis tef* and *Eleusine coracana* were identified as the staple forage species of common warthog population. They accounted for 68.2% of the dry season diet of common warthogs.The top three staple forage species *Hyparrhenia rufa* (14.6%), *C. nlemfuensis* (13.8%), and *C. dactylon* (10.6%) contributed for 48.2% of the dry season diet (Table 30).On the other hand, *H. rufa, H. hirta,* and, *B. ethiopum* were less in the diet during the wet season.

Cyperus fischerianus, D.abyssinica, C. dactylon, C.nlemfuensis, and *A. abyssinicus* decreased during the dry season. However, *Sesbania sesban* and *D. africanum* were foraged only during the wet season in GCHA.

Table 30. Forage species (mean ± SE) that contributed ≥1% to the diet of common warthog either during the wet or dry season in GCHA.

Family	Forage species	Wet	Dry	$\chi 2$, df=1
Graminoids= 13				
Cyperaceae	*Cyperus fischerianus*	5.8±1.72	2.6±1.01	1.2
Poaceae	*Digitaria abyssinica*	7.2±1.71	2.8±1.37	1.94
Poaceae	*Eragrostis tef*	0	5.2±1.63	0
Poaceae	*Zea mays*	0	2.4±1.01	0
Poaceae	*Sorghum bicolor*	0	2.8±1.17	0
Poaceae	*Eleusine coracana*	0	4.2±1.72	0
Poaceae	*Cynodon dactylon*	15.2±1.02	10.6±2.33	0.82
Poaceae	*Cynodon nlemfuensis*	23.4±2.42	13.8±1.33	2.47
Poaceae	*Hyparrhenia rufa*	9.6±2.15	14.6±1.36	1.03
Poaceae	*Hyparrhenia hirta*	2.8±1.6	9.8±1.72	3.89
Poaceae	*Panicum maximum*	2.2±1.5	2.8±1.6	0.07
Poaceae	*Pennisctum nubicwn*	2.6±1.01	0	0
Poaceae	*Andropogon abyssinicus*	8.2±2.04	5.8±1.72	0.41
Herbs= 9				
Arecaceae	*Borassusa ethiopum*	3±1.3	1.6±0.8	1.65
Combretaceae	*Terminalia brownii*	1.1±0.86	2.2±1.72	0
Commelinaceae	*Commelina benghalensis*	0.7±0.51	1.4±1.01	0
Dracaenaceae	*Dracaena steudneri*	1.1±0.58	2.2±1.17	0
Fabaceae	*Sesbania sesban*	1.7±0.49	3.4±1.51	0
Moraceae	*Ficus sycomorus*	0	2.8±0.72	0
Moraceae	*Ficus sur(F. capensis*	0	2.6±1.62	0
Moraceae	*Ficus vasta*	0	2.4±1.01	0
Salicaceae	*Salix mucronata*	1.4±1.01	2.8±0.75	0.46
Shrub = 1				
Apiaceae	*Diplolophium africanum*	1.5±0.61	3±1.41	0
Climber= 1	*Stephania abyssinica*	1.2±0.51	2.4±1.01	0
	Total	94.6	92.2	13.94

In HADCHA,*C. fischerianus, D. abyssinica, C. dactylon, C. nlemfuensis, H. rufa,H. hirta, S. poiretiana, A. abyssinicus* and *S. sesban* were identified as the staple forage species of warthogs during the wet season. These nine staple forage species accounted for 74% of the wet season diet. Out of these, the top three staple forage species C. *nlemfuensis* (22.8%), *C. dactylon* (18.8%), and *D. abyssinica* (6.8%) accounted for 48.4% of the wet season diet (Table 31).During the dry season,*C. fischerianus, C. dactylon, C. nlemfuensis, H. rufa, A. abyssinicus,B. ethiopum* and *Eragrostis tef* were identified as the staple forage species of common warthogs. They accounted for 62% of the dry season diet of common warthog. The top three staple forage species were *C. nlemfuensis* (15.2%), *C. dactylon* (13.8%) and *H. rufa* (12.4%) whichaccounted for41.4% of the dry season diet composition (Table 31).However, *H. rufa, B. ethiopum* and *A. abyssinicus* were less in the diet during the wet season but *C. fischerianus,D. abyssinica, C. dactylon, C. nlemfuensis H. hirta,* were less during the dry season.

During the wet season, the staple forage species of the GCHA and HADCHA were the same with the exception of *H. hirta,S. poiretiana* and *D. africanum.*The first two of these forage species supplemented the staple forage species of common warthog in HADCHA and the last forage species wasone of the staple foods in GCHA. During the dry season, both study areas had similar staple forage species apart from *H. hirta, Eleusine coracana* and *C. fischerianus.H. hirta* and *E. coracana* were the staple forage species in GCHA whereas *C. fischerianus* was among the forage species in HADCHA. The annual staple forage species of both study areas differed by *B.ethiopum* and *H. hirta*. Hence, B. *ethiopum* was the annual staple forage species in GCHA while *H. hirta* was one of the yearly staple forage species in HADCHA.

Table31.Forage species (mean ± SE) that contributed ≥1% in the diet of common warthog either during the wet or dry season in HADCHA

Family	Forage species	Wet	Dry	$\chi 2$, df=1
Graminoids= 16				
Cyperaceae	*Cyperus fischerianus*	6.2±2.07	5.8±2.13	0.001
Poaceae	*Digitaria abyssinica*	6.8±1.72	2.2±0.74	1.98
Poaceae	*Eragrostis tef*	0	6.4±1.49	0
Poaceae	*Zea mays*	0	1.8±1.72	0
Poaceae	*Sorghum bicolor*	0	2.6±1.77	0
Poaceae	*Eleusine coracana*	0	2.8±1.46	0
Poaceae	*Cynodon dactylon*	18.8±2.56	13.8±1.47	0.39
Poaceae	*Cynodon nlemfuensis*	22.8±1.17	15.2±1.22	0.94
Poaceae	*Hyparrhenia rufa*	6.2±1.09	12.4±1.64	2.64
Poaceae	*Eragrostis spp,*	1.8±1.45	2.4±1.02	0.146
Poaceae	*Hyparrhenia hirta*	3.4±1.85	2.8±1.16	0.08
Poaceae	*Hyparrhenia varibilis*	2.8±1.17	2.4±1.01	0.006
Poaceae	*Panicum maximum*	2±1.09	2.6±1.80	0.14
Poaceae	*Pennisctum nubicwn*	2.2±1.17	0	0
Poaceae	*Setaria poiretiana*	3.2±1.16	0	0
Poaceae	*Andropogon abyssinicus*	3.4±1.02	4.6±1.62	0.29
Herbs=9				
Arecaceae	*Borassusa ethiopum*	1.4±1.01	3.8±1.33	1.33
Combretaceae	*Terminalia brownii*	1.6±1.02	0	0
Commelinaceae	*Commelina benghalensis*	1.2±0.74	0	0
Dracaenaceae	*Dracaena steudneri*	1.4±0.48	0	0
Fabaceae	*Sesbania sesban*	3.2±1.72	0	0
Moraceae	*Ficus sycomorus*	0	1.8±0.75	0
Moraceae	*Ficus sur* (*F. capensis*)	0	2.8±1.32	0
Moraceae	*Ficus vasta*	0	2.6±1.85	0
Myrtaceae	*Syzygium guineense*	1.2±0.4	2.6±0.80	0.64
Shrubs=2				
Apiaceae	*Diplolophium africanum*	1.2±0.16	0	0
Malvaceae	*Hibiscus macranthus*	1.2±0.75	0	0
Climber = 1				
Menispermaceae	*Stephania abyssinica*	1.8±0.74	0	0
	Total	93.8	91.4	8.583

In GCHA, graminoids were the most frequently available foragespecies of common warthog population during the wet season (87.1. % ±7.21)and during the dry seasons (83.3% ±5.99)(Fig. 39).Herbs formed 10.1%±0.11 during the wet season and 16.7%±1.27 during the dry season available foraged species. Shrubs and climbers were the less available foraged species during both seasons. Hence, forage categories available were significantly different ($F_{3\ 4}$= 124.9, P < 0.05) during the wet and dry seasons.

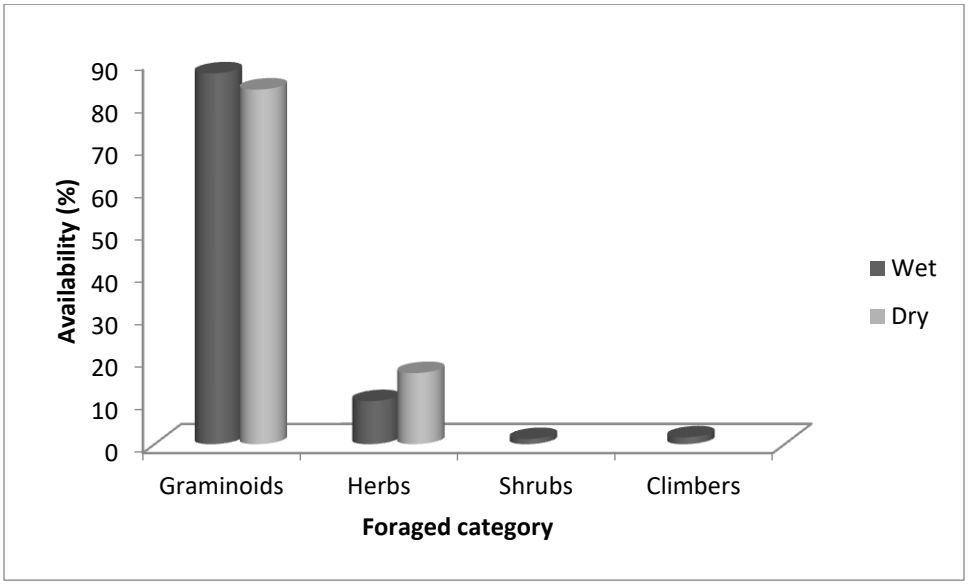


Figure 39. Forage categories (%) available in GCHA during the wet and dry seasons.

In HADCHA, graminoids were the most frequently available foraged categories of common warthogs during the wet season (88.3% ±5.74) and during the dry season (90.9% ±4.74) (Fig.40).Herbs formed 9%±0.28 during the wet and 9.1%±0.89 during the dry season. Shrubs and climbers were the less available foraged categories during the wet and dry seasons. Therefore, forage categories available were significantly different (F3, 4 = 137.4, P < 0.05)

between the wet and dry seasons. Conversely, the two study areas did not show significant variation ($\chi 2 = 0.43$, df=1, P >0.05) in the available foraged categories.

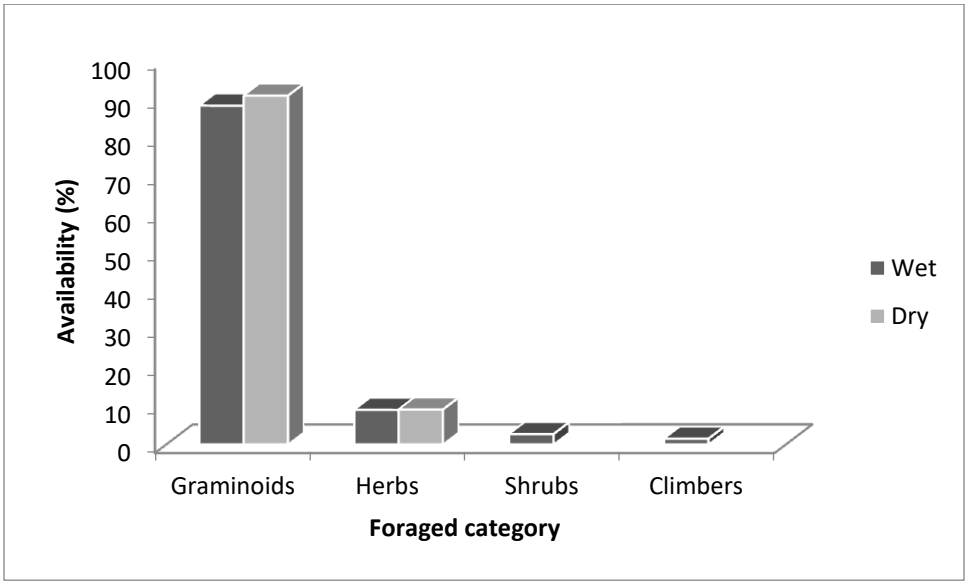


Figure40. Forage categories (%) available in HADCHA during the wet and dry seasons.

Seasonal forage availability of 24 species, which contributed ≥1% in the diet of common warthogs during the wet and dry seasons were identified in GCHA (Fig.41). Ten foraged species were available during both seasons, seven plant species were available during the wet season and the other seven forage species were available only during the dry season. The top five forage species *C. nlemfuensis* (18.6%), *H. rufa* (17.55%), *H. hirta* (15.1%), *C. dactylon* (13.3%), and *D. abyssinica* (5.1%) covered 69.65% of the available forages to common warthogs during both seasons. The proportion of seasonal availability of *C. nlemfuensis* ($\chi 2$=0.34, df =1, P > 0.05), *H. rufa* ($\chi 2$=0.23, df =1, P > 0.05), *H. hirta* ($\chi 2$=0.39, df =1, P > 0.05), *C. dactylon* ($\chi 2$=0.38, df =1, P > 0.05), and *D. abyssinica* ($\chi 2$=0.06, df =1, P > 0.05) were not significantly different during the wet and dry seasons.

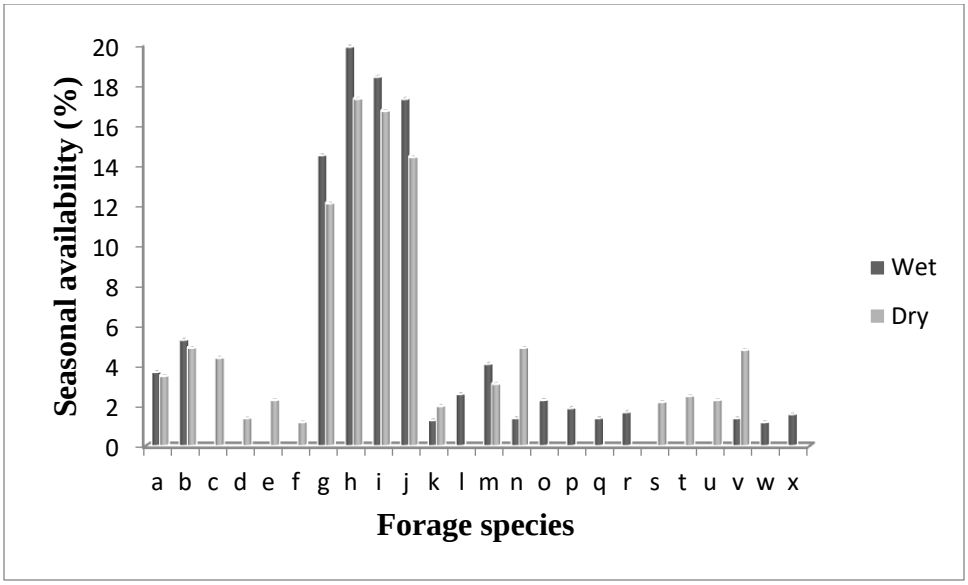


Figure41. Seasonal changes in the availability (%) of forage species recorded in more than 5 quadrats that contributed ≥1% in the diet of common warthog either during the wet or dry seasons in GCHA (a=*C. fischerianus*, b=*D. abyssinica*, c=*E. tef*, d=*Z. mays*, e=*S. bicolor*, f=*E. coracana*, g=*C. dactylon*, h=*C. nlemfuensis*, i=*H. rufa*, j= *H. hirta*, k=*P. maximum*, l= *P. nubicwn*, m= *A.abyssinicus*, n=*B. ethiopum*, o= *T. brownie*, p= *C. benghalensis*, q= *D. steudneri*, r= *S. sesban*, s= *F. sycomorus*, t= *F. sur*, u= *F. vasta*, v=*S. mucronata*, w=*D. africanum*, x=*S.abyssinica*).

In HADCHA, 28 seasonally available forage species, which contributed ≥1% in the diet of common warthog during the wet and dry seasons were identified (Fig. 42). Twelve forage species were available during both seasons, nine species were available only during the wet season and seven species were accessible only during the dry season. The top five forage species *Eragrostis* spp(15%), *H. rufa* (14.1%), *C. nlemfuensis* (13.65%), *H. hirta* (12.65%),and *C. dactylon* (12.05%), accounted for 67.45% of the available forage during both seasons. The seasonal availability during the wet and the dry seasons of *Eragrostis* spp ($\chi 2$=0.003, df =1, P > 0.05), *H. rufa* ($\chi 2$=0.029, df =1, P > 0.05), *C. nlemfuensis* ($\chi 2$=0.006, df =1, P > 0.05), *H. hirta*

($\chi2$=0.029, df =1, P > 0.05), and *C. dactylon* ($\chi2$=0.002, df =1, P > 0.05), were not significantly different

The top five seasonal availability proportion forage species of both study areas showed similarity in *C. nlemfuensis*, *H. rufa*, *H. hirta* and *C. dactylon*,but differed by *Eragrostis* spp and *D. abyssinica*. *Eragrostis* spp was one of the most available forage species in HADCHA, whereas *D. abyssinica* was the more available forage species in GCHA. Moreover, the two study areas were not significantly different ($\chi2$=1.12 df =1, P > 0.05) in the seasonal availability proportion of forage species of common warthogs.

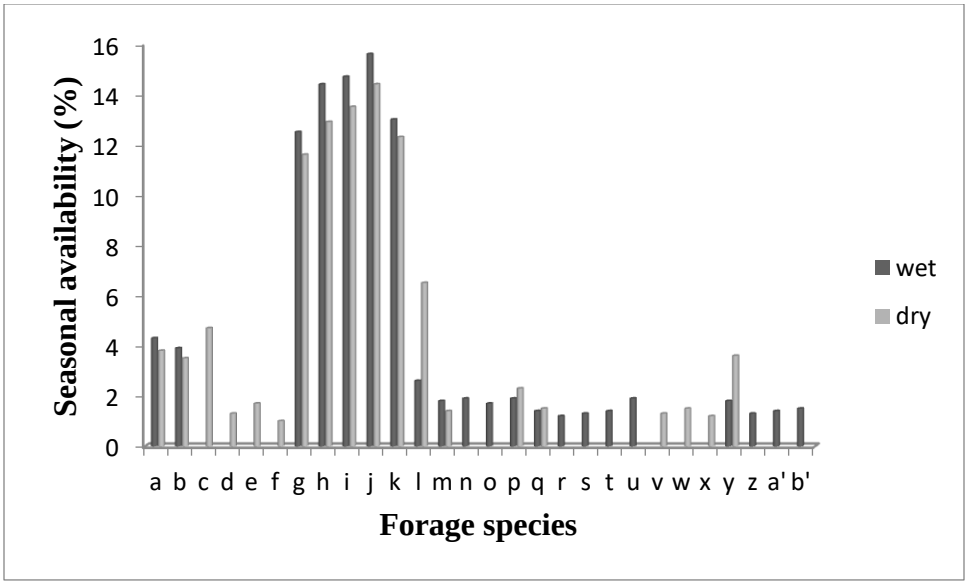


Figure 42. Seasonal changes in the availability (%) of forage species recorded from more than 5 quadrats and contributed ≥1% in the diet of common warthog either during the wet or dry seasons in HADCHA (a=*C. fischerianus*, b=*D. abyssinica*, c=*E. tef*, d=*Z. mays*, e=*S. bicolor*, f=*E. coracana*, g=*C. dactylon*, h=*C. nlemfuensis*, i=*H. rufa*, j= *Eragrostis spp*, k= *H.hirta*, l= *H.varibilis*,m=*P. maximum*, n= *P. nubicwn*, o= *S. poiretiana*, p= *A.abyssinicus*, q=*B. ethiopum*, r= *T. brownie*, s= *C. benghalensis*, t= *D.*

steudneri, = u. *sesban,* v= *F. sycomorus,* w= *F. sur*, x= *F. vasta,* y=*S. mucronata*, z=*D. africanum*, a'= *H. macranthus*, b'=*S.abyssinica*)

Acceptability index was calculated for 16 and 17 foraged species, which contributed ≥1% in the diet of the common warthog during the wet and dry seasons, respectively, in GCHA (Fig. 43). During the wet season, seven species were high acceptability (61.48%), five moderate (24.89%) and four were less acceptability (13.61%) by the common warthogs. During the dry season, five were high acceptability (47.23%), six were moderate (34.44%) and the other six less acceptability (18.31%) by the common warthogs. *C. fischerianus,D. abyssinica, C. dactylon, C. nlemfuensis, H. rufa,* and*A. abyssinicus* were high acceptability during both seasons. Similarly, *C. dactylon, C. nlemfuensis* and A. *abyssinicus* were the top three species which showed high acceptability during the wet and dry seasons. *Hyparrhenia hirta,* was high acceptability during the wet season which was less acceptability during the dry season but the difference was not significant ($\chi 2=0.22$, df=1, $P<0.05$). *Panicum maximum* was moderate acceptability during the wet season andless acceptability during the dry season. *Borassusa ethiopum* was moderate acceptability during the dry season but less acceptability during the wet season.

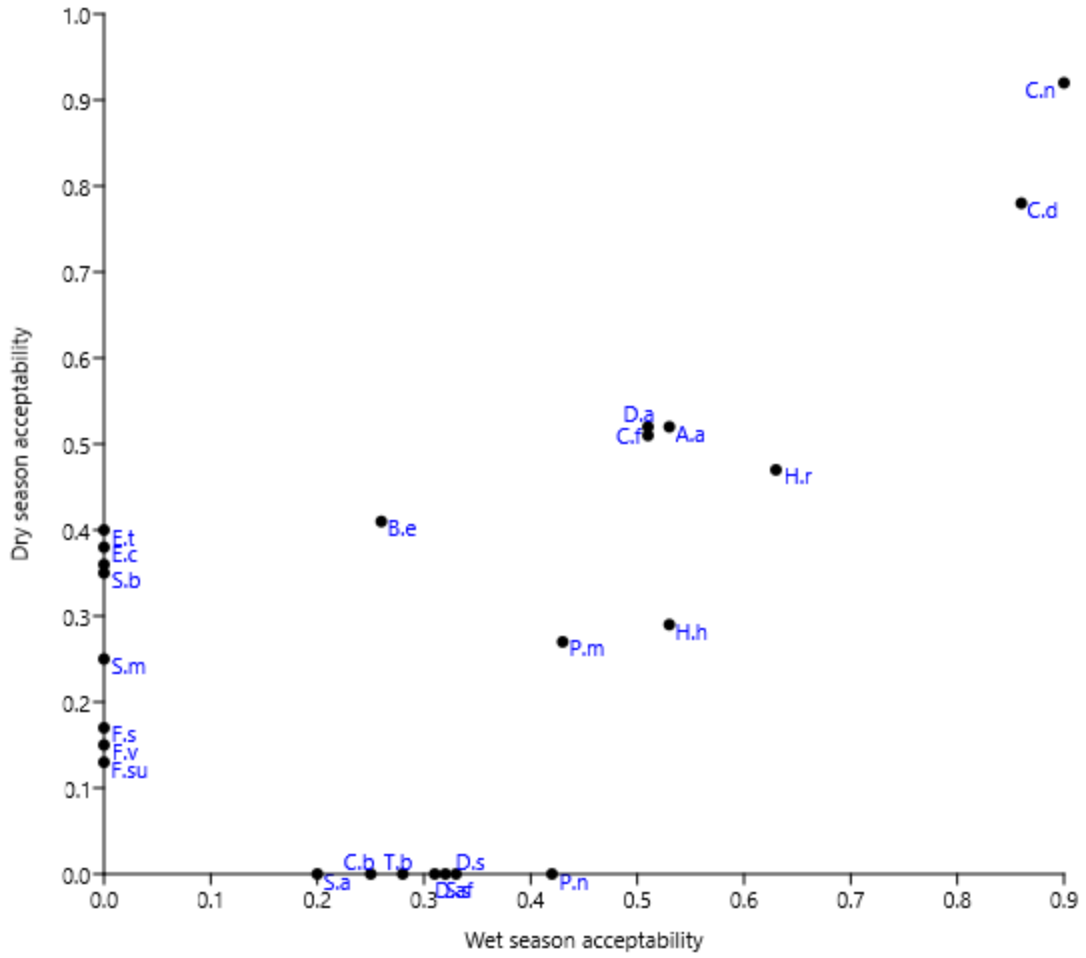


Figure 43. Seasonal acceptability of forage species that contributed ≥1% to the diet of common warthogs either during the wet or dry seasons in GCHA.

In HADCHA, acceptability index was calculated for 21 and 17 foraged species, which contributed ≥1% to the diet of the common warthog and dry seasons, respectively (Fig. 44). Of these, seven (56.78%) were high acceptability, eight (29.27%) were moderate whereas six (13.93%) were less acceptability by the common warthogs. During the dry season, five (46.9%) were high acceptability, six (25.28%) were moderate and the other six (27.8%) were less

acceptability by the common warthogs. *Cyperus fischerianus*, *D.abyssinica, C. dactylon, C. nlemfuensis, H. rufa,* and *A. abyssinicus* showed high acceptability during both seasons. Hence, C. *dactylon, C. nlemfuensis* and *C. fischerianus* were the top three species, which were high acceptability during the wet and dry seasons. On the other hand, *D. abyssinica, Setaria poiretiana* and *Syzygium guineense* were high acceptability during the wet season and less acceptability during the dry season, but they revealed insignificant variation ($P<0.05$). *Borassusa ethiopum* showed low acceptability during the wet season and high acceptability during the dry season. *Hyparrhenia hirta* ,and *H.varibilis* were moderate acceptability during the wet season whereas less acceptability during the dry season.

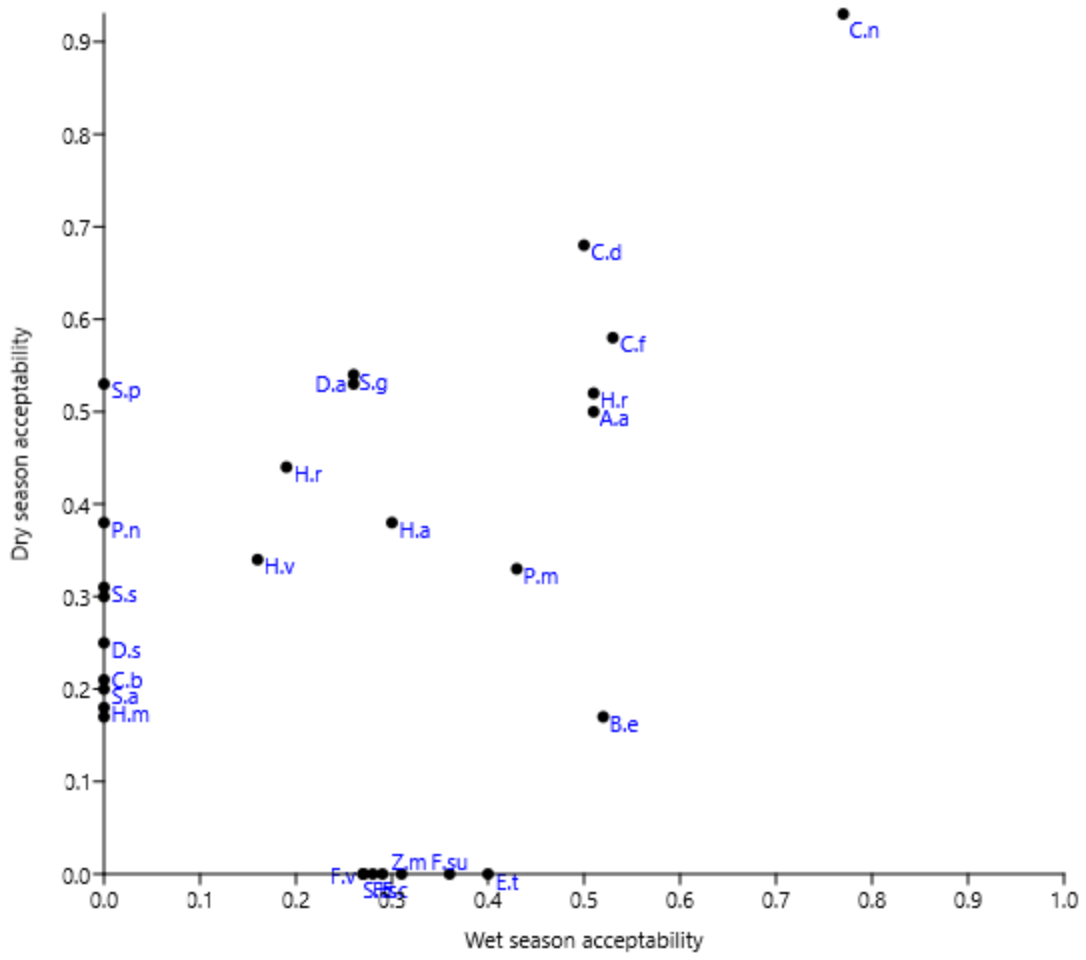


Figure 44. Seasonal acceptability of forage species that contributed ≥1% to the diet of common warthogs either during the wet or dry seasons in HADCHA

The two study areas were different in foraged species acceptability indexes of both seasons. *Digitaria abyssinica* had high acceptability index during both seasons in GCHA, whereas it hadhigh acceptability during the wet season and less acceptability during the dry season in HADCHA. *Hyparrhenia rufa* and *H. hirta* were high acceptability during the wet season. However, *H. rufa*had moderate and *H. hirta* had less acceptability during the dry season in

GCHA. Similarly, in HADCHA, *H. rufa* had high acceptability during both seasons while *H. hirta* had moderate acceptability during the wet season and less acceptability during the dry season. *Panicum maximum* had moderate and less acceptability during the wet and dry seasons, respectively in GCHA but moderate acceptability during both seasons in HADCHA. *Cyodon dactylon* and *C. nlemfuensis* were the top two species, which had high acceptability during the wet and the dry seasons in both study areas.

The mean proportion of organic carbon (OC) in salt licked common warthogs ingested varied from 1.91±0.39 (Gimbicho) to 2.92±0.89 (Robe) during the wet season. On the other hand, it ranged from 1.8 ±0.54 (Miesso) to 2.94±0.08 (Desa) during the dry season. Seasonal mean proportion of organic carbon in Miesso ($t=-0.22$, $df=1$, $P>0.05$), Seba ($t=0.36$, $df=1$, $P>0.05$), Lemana ($t=-0.107$, $df=1$, $P>0.05$), Robe ($t=0.16$, $df=1$, $P>0.05$), Desa ($t=1.28$, $df=1$, $P>0.05$) and in Dodeta ($t=1.43$, $df=1$, $P>0.05$) were not significantly different. In contrast, the mean proportion of organic carbon in Menjiko ($t= 5.21$, $df=1$, $P<0.01$) and in Gimbicho ($t= -4.08$, $df=1$, $P<P0.05$) revealed significant variation between wet and dry seasons (Table32).

Table32. M± SE of proportion of mineral elements and pH found in salt licking of common warthog in GCHA and HADCHAduring the wet (w) and dry (d) seasons

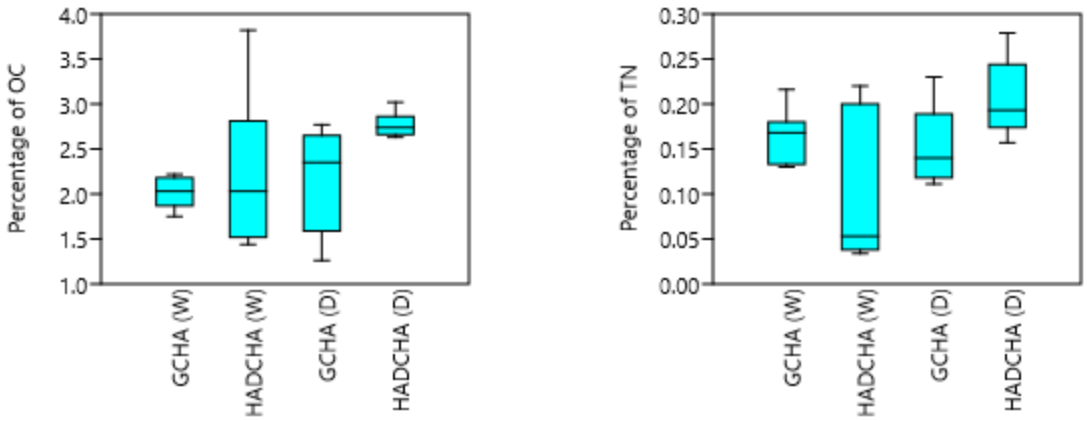
Study site	Season	pH	OC	TN
Miesso	w	4.87±0.03	1.95±0.08	0.14±0.01
	d	4.84±0.02	1.8±0.54	0.136±0.017
Seba	w	4.98±0.14	1.91±0.16	0.193±0.023
	d	4.72±0.18	2.11±0.52	0.141±0.02
Lemana	w	5.11±0.04	2.1±0.07	0.17±0.004
	d	4.8±0.44	2.13±0.22	0.125±0.014
Menjiko	w	4.87±0.29	2.10±0.07	0.15±0.017
	d	5.13±0.16	2.71±0.06	0.21±0.02
Robe	w	5.15±0.04	2.92±0.89	0.129±0.09
	d	4.23±0.01	2.78±0.075	0.19±0.005
Desa	w	4.94±0.18	2.38±0.43	0.043±0.01
	d	5.16±0.25	2.94±0.08	0.236±0.008
Gimbicho	w	4.8±0.005	1.91±0.39	0.09±0.047
	d	4.34±0.06	2.74±0.08	0.17±0.002
Dodeta	w	5.34±0.41	1.95±0.51	0.175±0.02
	d	4.7±0.115	2.68±0.05	0.218±0.006

The proportion of total nitrogen (TN) mean in salt lick common warthog ingested varied from 0.043±0.01 (Desa) to 1.93±0.023 (Seba) during the wet season. On the other hand, the proportion ranged from 0.125 ±0.014 (Lemana) to 0.236±0.08 (Desa) during the dry season. Seasonal mean proportion of total nitrogen in Miesso ($t=–0.22$, $df=1$, $P>0.05$), in Seba ($t=–1.71$, $df=1$, $P>0.05$), in Menjiko ($t=1.69$, $df=1$, $P>0.05$), in Robe ($t=–0.75$, $df=1$, $P>0.05$), in Gimbicho ($t=–1.75$, $df=1$, $P>0.05$) and in Dodeta ($t=0.65$, $df=1$, $P>0.05$) were not significantly different. In contrast, the mean proportion of total nitrogen in Lemana ($t= 3.08$, $df=1$, $P<0.05$) and in Gimbicho ($t= 15.06$,

df=1, P<0.001) revealed significant variation between the wet and dry seasons (Table 32). The mean proportion pH in salt licking common warthog consumed varied from 4.8±0.005 (Gimbicho) to 5.34±0.41 (Dodeta) during the wet season. On the other hand, it was varied from 4.23 ±0.01 (Robe) to 5.16±0.25 (Desa) during the dry season.

During the wet season, the mean proportion of organic carbon in salt licking common warthog ingested was 2±0.05 in GCHA and 2.29±0.59 in HADCHA. But they were insignificantly different ($F_{1\ 14}$= 0.94, P > 0.05). The mean proportion of organic carbon was less in GCHA (2.19 ±0.19) and more in HADCHA (2.78±0.04). They showed significant variation ($F_{1\ 14}$= 9.08, P < 0.05) during the dry season(Fig. 45A).

The mean total nitrogenproportion in salt licking common warthog ingested was higher in GCHA (1.32±0.16) and lower in HADCHA (0.88±0.11) during the wet season. But they showed insignificant variation ($F_{1\ 14}$= 3.67, P > 0.05). However, the mean proportion of total nitrogen was lower in GCHA (0.153 ±0.014) and higher in HADCHA (0.206±0.014) during the dry season. They showed significant variation ($F_{1\ 14}$= 7.06, P < 0.05) in the amount of total nitrogen (Fig.45 B).



A. Study area and season B. Study area and season

Figure 45. Percentage of organic carbon; OC (A) and percentage total nitrogen; TN (B) in the salt licking by common warthog in GCHA and HADCHA

The mean phosphorous concentration in salt licking common warthog ranged from 4.9±0.19 ppm (Lemana) to 7.1±0.38 ppm (Dodeta) during the wet season. Similarly, it varied from 2.95 ±0.17 P ppm (Robe) to 13.9±8.82 Pppm (Dodeta) during the dry season. Seasonal mean concentration of P in Seba (t=0.65, df=1, P>0.05), in Lemana (t=0.67, df=1, P>0.05), in Menjiko (t=0.82, df=1, P> 0.05), in Desa (t=1.62, df=1, P>0.05), and in Dodeta (t=–0.78 df=1, P>0.05) did not show significant variation. In contrast, the mean concentration of P in Miesso (t= –3.57, df=1, P< 0.05), in Robe (t= 21.37, df=1, P< 0.001), and in Gimbicho (t= –13.58, df=1, P< 0.05) revealed significant variation between the wet and dry seasons (Table33).

Potassium mean concentration in salt lick common warthog ranged from 0.11±0.014 meq/100g (Desa) to 0.246±0.01 meq/100g (Robe) during the wet season. Similarly, concentration varied from 0.047 ±0.003K meq/100g (Gimbicho) to 0.32±0.06 K meq/100g (Menjiko) during the dry

season. However, seasonal mean concentration of K in Miesso (t=1.25, df=1, P>0.05), in Seba (t=–0.78, df=1, P>0.05), Lemana (t=1.14, df=1, P> 0.05) and Dodeta (t=–1.66, df=1, P>0.05) did not show significant difference. The mean concentration of K in Menjiko (t= –3.04, df=1, P<0.05), Robe (t= 24.43, df=1, P< 0.001), Gimbicho (t= –3.72, df=1, P< 0.01) and in Desa (t= 2.53, df=1, P< 0.05) revealed significant variation between the wet and dry seasons (Table33).

Table 33. Concentration of mineral elements found in salt lickingof common warthogs in GCHA and HADCHA during the wet (w) and dry (d) seasons

Study site	Season	P ppm	K meq/100g	Na meq/100g	Mg meq/100g	Ca meq/100g
Miesso	w	5.09±0.03	0.131±0.01	0.06±0.0005	0.15±0.064	0.63±0.17
	d	4.66±0.12	0.318±0.15	0.028±0.013	0.63±0.115	1.31±0.24
Seba	w	5.69±0.16	0.125±0.008	0.013±0.002	0.52±0.069	2.67±1.44
	d	6.23±0.81	0.144±0.023	0.015±0.01	0.37±0.088	0.78±0.093
Lemana	w	4.9±0.19	0.122±0.122	0.032±0.01	0.48±0.032	3.84±0.64
	d	5.37±0.62	0.88±0.66	0.011±0.001	0.75±0.07	0.63±0.57
Menjiko	w	6.15±1.02	0.118±0.008	0.031±0.009	0.828±0.31	3.7±0.51
	d	5.13±0.75	0.32±0.06	0.01±0.001	1.26±0.16	0.98±0.07
Robe	w	6.68±0.03	0.246±0.01	0.013±0.0005	0.93±0.09	1.47±0.68
	d	2.95±0.17	0.05±0.001	0.023±0.007	0.09±0.003	0.337±0.01
Desa	w	5.3±0.16	0.11±0.014	0.017±0.001	0.48±0.28	2.17±0.55
	d	8.15±1.75	0.204±0.021	0.022±0.003	2.39±0.24	4.55±1.04
Gimbicho	w	6.52±0.18	0.126±0.03	0.026±0.01	0.53±0.37	1.65±1
	d	2.96±0.18	0.047±0.003	0.017±0	0.084±0.003	0.325±0.005
Dodeta	w	7.1±0.38	0.207±0.01	0.012±0.002	0.91±0.31	1.88±0.19
	d	13.9±8.82	0.16±0.003	0.08±0.006	1.59±0.024	3.6±1.25

The mean sodium concentration in salt lick common warthog varied from 0.012±0.002 meq/100g (Dodeta) to 0.06±0.005meq/100g (Miesso) during the wet season. Likewise, the concentration ranged from 0.01 ±0.001 Na meq/100g (Menjiko) to 0.08±0.006 meq/100g (Dodeta) during the dry season. Seasonal mean concentration of Na in Seba (t=0.145, df=1, P>0.05), Menjiko (t=–1.51, df=1, P>0.05), Robe (t=–1.33, df=1, P> 0.05), Desa (t=–1.48, df=1, P> 0.05), Gimbicho (t=0.75, df=1, P> 0.05), and in Dodeta (t=–1.18, df=1, P>0.05) revealed insignificant variation. In contrast, the mean concentration of Na in Miesso (t= 2.16, df=1, P< 0.05) and in Lemana (t= 2.04, df=1, P< 0.001), showed significant variation between the wet and dry seasons (Table 33).

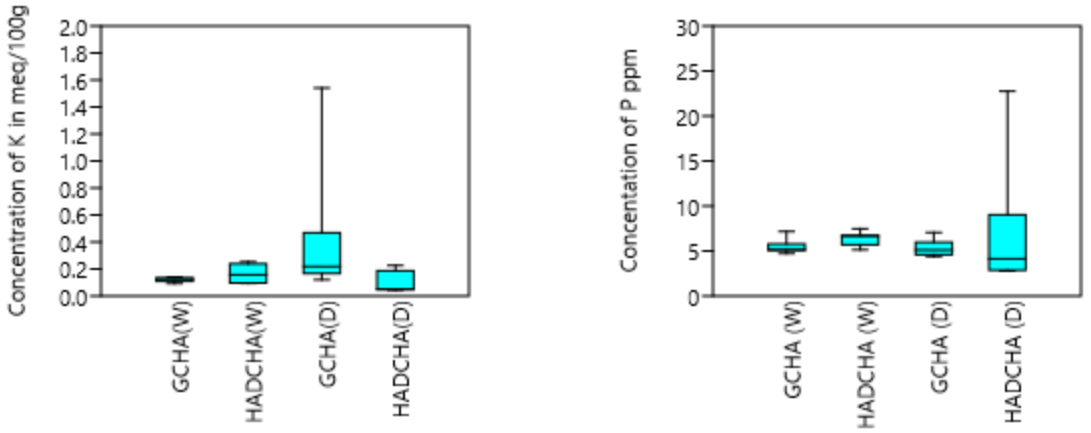
The mean magnesium concentration in salt lick common warthog ate varied from 0.15±0.064 meq/100g (Miesso) to 0.93±0.09 meq/100g (Robe) during the wet season. Similarly, the concentration ranged from 0.084 ±0.003 Mg meq/100g (Gimbicho) to 2.39±0.24meq/100g (Desa) during the dry season. Seasonal mean concentration of Mg in Seba (t=–1.33, df=1, P>0.05), Menjiko (t=–0.79, df=1, P>0.05), Gimbicho (t=1.21, df=1, P> 0.05), and in Dodeta (t=1.72, df=1, P> 0.05) did not show significant variation between the wet and dry seasons. In contrast, the mean concentration of Mg in Miesso (t= –3.67, df=1, P< 0.05) and in Lemana (t= –3.55, df=1, P< 0.05), in Robe (t= 8.78, df=1, P< 0.001) and in Desa (t= 5.16, df=1, P< 0.001) showed significant differences between the wet and dry seasons (Table 33).

The mean calcium concentration in salt licking common warthog ranged from 0.63±0.17 meq/100g (Miesso) to 3.84±0.64 meq/100g (Lemana) during the wet season. Similarly, the concentration varied from 0.325 ±0.005 Ca meq/100g (Gimbicho) to 4.55±1.04 meq/100g (Desa)

during the dry season. Seasonal mean concentration of Ca in Seba (t=–1.31, df=1, P>0.05), in Menjiko (t=–1.89, df=1, P>0.05), Robe (t=1.21, df=1, P> 0.05), Gimbicho (t=1.3, df=1, P> 0.05) and in Dodeta (t=1.35, df=1, P>0.05) did not show significant difference between the wet and dry seasons. In contrast, the mean concentration of Ca in Miesso (t= –2.31, df=1, P< 0.05) and in Lemana (t= 3.74, df=1, P< 0.05), and in Desa (t= 2.02, df=1, P< 0.05) revealed significant variation between the wet and dry seasons (Table 33).

The mean K concentration in salt licking common warthog was less inGCHA (0.122±0.005) and higher in HADCHA (0.17±0.02) during the wet season. Thus, they showed significant variation ($F_{1\ 14}$= 5.76, P < 0.05). During the dry season, the mean concentration of K was 0.41 ±0.17 in GCHA and 0.11±0.026 in HADCHA. But, the variation was insignificant ($F_{1\ 14}$= 3.18, P > 0.05) (Fig. 46 A).

During the wet season, the mean P concentration in salt licking common warthog was less in GCHA (5.46±0.27) and high in HADCHA (6.4±2.41). They showed significant difference ($F_{1\ 14}$= 6.01, P < 0.05). During the dry season, the mean concentration of P was 5.34 ±0.32 in GCHA and 6.99±2.41 in HADCHA. Hence, they showed insignificant variation ($F_{1\ 14}$= 0.46, P > 0.05) (Fig. 46 B).

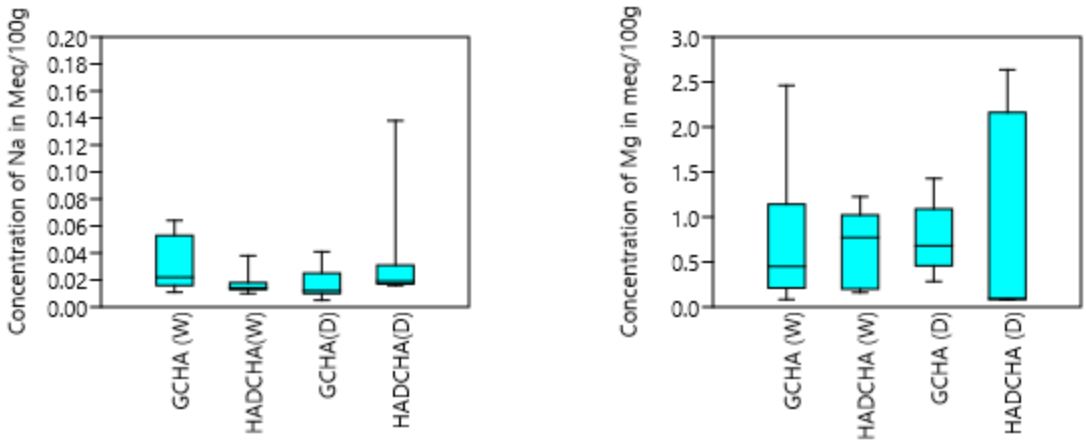


A. Study area and season B. Study area and season

Figure 46. Percentage of K (A) and percentage P (B) in the salt licking by common warthog in GCHA and HADCHA

The mean Na concentration in salt lick common warthogs was 0.033±0.006 in GCHA and 0.017±0.003 in HADCHA during the wet season. However, thevariation was insignificant ($F_{1\ 14}$= 4.43, P > 0.05). Likewise, during the dry season, the mean Na concentration was 0.016 ±0.004 in GCHA and 0.035±0.014 in HADCHA. But, they showed insignificant variation ($F_{1\ 14}$= 1.63, P > 0.05) (Fig. 47 A).

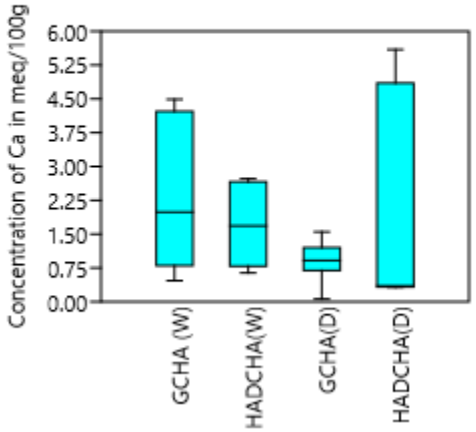
The mean Mg concentration in salt licking common warthogs was 0.74±0.27 in GCHA and 0.71±0.134 in HADCHA during the wet season. However, they showed insignificant variation ($F_{1\ 14}$= 0.005, P > 0.05). Similarly, during the dry season, the mean Mg concentration was 0.75 ±0.129 in GCHA and 1.04±0.38 in HADCHAwith insignificant variation ($F_{1\ 14}$= 0.51, P > 0.05) (Fig. 47 B).



A. Study area and season B. Study area and season

Figure 47. Percentage of Na (A) and percentage Mg (B) in the salt licking by common warthogs in GCHA and HADCHA

The mean Ca concentration in salt lick common warthog was 2.96±0.58 in GCHA and 1.79±0.27 in HADCHA during the wet season. However, they showed insignificant variation ($F_{1\ 14}$= 1.44, P > 0.05). Likewise, during the dry season, the mean Ca concentration was 0.93 ±0.15 in GCHA and 2.2±0.78 in HADCHA. They showed insignificant variation ($F_{1\ 14}$= 2.56, P > 0.05) (Fig 48).



Study area and season

Figure 48. Concentration of Ca in the salt lickingof common warthog in GCHA and HADCHA

6.5. Nutrient quality

In GCHA, the mean proportion of fecal carbon (FC) content of common warthog was 23.5% during the wet seasonand 23.1%) during the dry season. Hence, they did not show significant difference ($F_{1\ 3} = 0.027$, $P > 0.05$). Likewise,in HADCHA the mean proportion of fecal carbon contentwas 25.04% during the wet season and 25.62% during the dry season. Hence, they revealed insignificant variation ($F_{1\ 3} = 0.022$, $P > 0.05$) (Fig. 49). Therefore, the mean fecal carbon contentof common warthog did not show significance difference (t=–1.01, df=7, P>0.05) between the two study areas. On the other hand, in GCHA, mean proportion of dietary carbon (DC) content of common warthog was 8.74% during the wet season and 16.6% during the dry season. Hence, they were significantly different ($F_{1\ 3} = 5.76$, $P < 0.05$). However, in HADCHA the mean proportion of dietary carbon content was 15.06% during the wet season and 16.52% during the dry season and they were insignificantly different ($F_{1\ 3} = 0.033$ $P > 0.05$) (Fig. 49).On the other hand, the mean fecal carbon content of common warthog did not reveal significance difference (t= –0.75,df=7, P>0.05) between the two study areas. Moreover, the mean proportion of fecal and dietary carbon contents of common warthog showed considerable variation ($F_{1\ 14} =$ 19.44, P <0.05) and negatively correlated (Spearman r=−0.17; P>0.05; N=16) in GCHA and HADCHA.

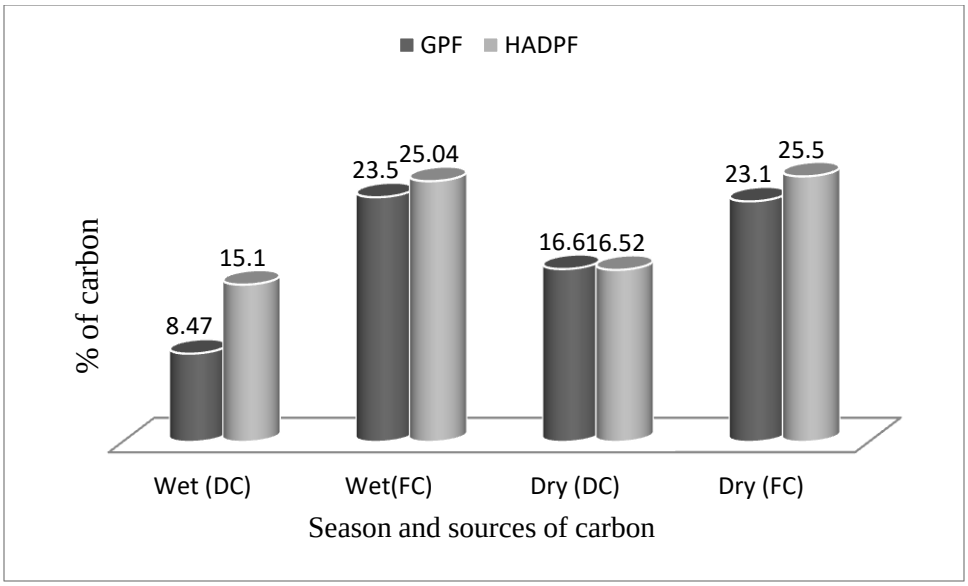


Figure 49. Mean seasonal fecal carbon (FC)and dietary carbon (DC) contents of common warthogs in GCHA and HADCHA

The mean proportion of fecal nitrogen (FN) contents of common warthog was 13.29 % during the wet season and 12.64% during the dry season. However, they were not significantly different ($F_{1\ 3} = 0.56$, $P > 0.05$). In HADCHA, the mean proportion of fecal nitrogen contentwas 13.66% during the wet season and 12.67% during the dry season. Hence, they showed insignificant variation ($F_{1\ 3} = 1.37$, $P < 0.05$) (Fig.50). However, the mean fecal nitrogen contents of common warthog did not show significant variation ($t = -0.39$, $df = 7$, $P > 0.05$) between the two study areas. On the other hand, in GCHA, the mean proportion of dietary nitrogen (DN) content of common warthog was 11.6% during the wet season and 9.11% during the dry season. They revealed significant difference ($F_{1\ 3} = 7.58$, $P < 0.05$). Similarly, in HADCHAthe mean proportion of dietary nitrogen contentwas 10.5% during the wet and 9.86 % during the dry season. But they revealed insignificant variation($F_{1\ 3} = 0.78$ $P > 0.05$) (Fig.50).The mean fecal nitrogen contents of common warthog did not show significant difference ($t = 0.22$,$df = 7$, $P > 0.05$) between GCHA and

HADCHA. Moreover, the mean proportion of fecal and dietary nitrogen contents of the animal showed considerable disparity ($F_{1\ 15}$ = 35.02, P <0.05) and positively correlated (Spearman r=0.31; P>0.05; N=16) in both study areas.

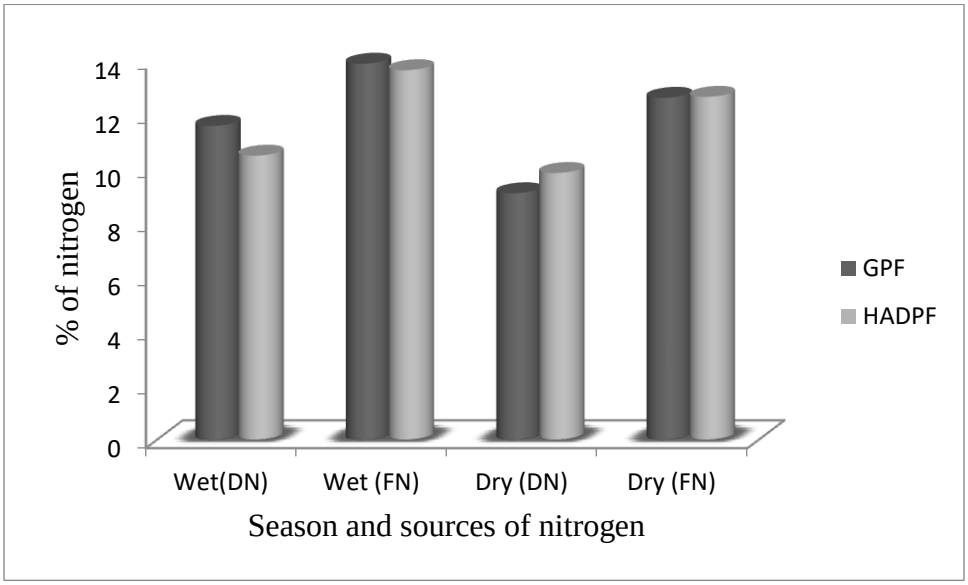


Figure50. Mean seasonal fecal nitrogen (FN) and dietary nitrogen (DN) contents of common warthogs in GCHA and HADCHA

Fecal phosphorous (FP) contents of common warthogs was found more in GCHA (1369.7 mg/100g± 911.22) than in HADCHA (1311 mg/100g ± 1221.6). Nevertheless, they did not show significance difference ($F_{1\ 3}$ = 0.52 P, > 0.05). On the other hand, dietary phosphorous (DP) content consumed warthogs attributed more in GCHA (1489.2 mg/100g± 1.762) andless in HADCHA (1312 mg/100g ± 490) (Fig. 51). However, they revealed insignificant differences ($F_{1\ 3}$ = 0.279, P > 0.05).The seasonal difference in the mean fecal and dietary phosphorous contents of common warthogs was not significant (t= –0.39,df=7, P>0.05)butthe fecal and dietary

phosphorous contents were highly correlated (Spearman r=0.916; P>0.05; N=16) in both study areas.

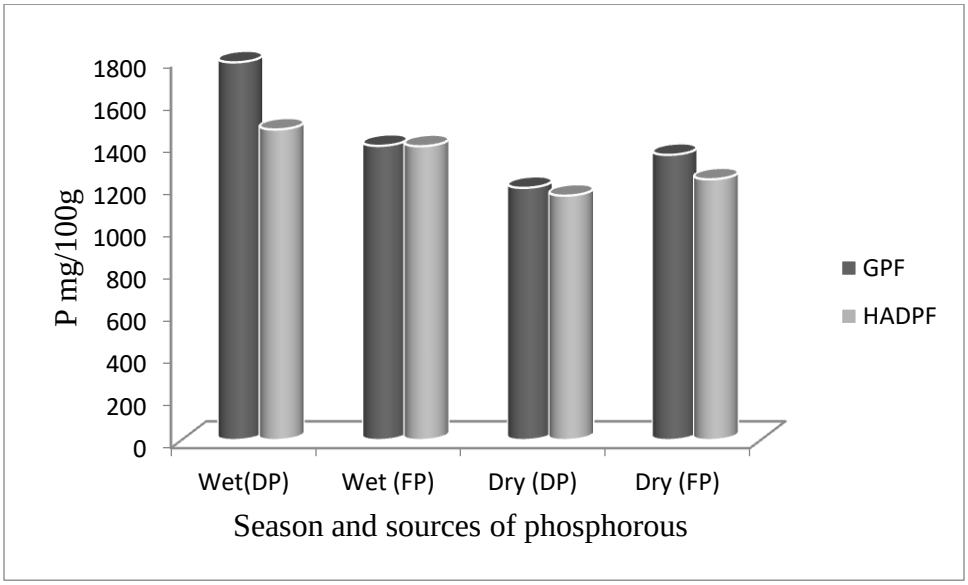


Figure 51. Mean seasonal fecal phosphorous (FP) and dietary phosphorous (DP) contents of common warthogs in GCHA and HADCHA.

The mean proportion of fecal crude protein (FCP) content was 85.37% during the wet and 79% the dry seasons in GCHA. Hence, they were significantly different ($F_{1\ 3}$ = 5.01, P <0.05). In HADCHA, seasonal mean proportion of FCP contentwas 83.05% during the wet and 79% during the dry seasons and showed insignificant variation ($F_{1\ 3}$ = 0.56, P > 0.05) (Fig. 52). The difference in the mean FCP contents between the two study areas was not significant (t= 0.39, df=7, P>0.05). On the other hand, in GCHAthe mean proportions of dietary crude protein (DCP) content of common warthog was 65.4% during the wet and 61.6% during the dry seasons and revealed insignificant differences ($F_{1\ 3}$ = 0.78, P > 0.05). However, in HADCHA,the mean proportion of DCP contentwas 72.52% during it was the wet and 56% during the dry season and

showed significant difference ($F_{1\ 3}$ = 7.57, P <0.05) (Fig. 52).Therefore, the mean DCP content of common warthogs was insignificantly different (t= –0.22,df=7, P>0.05) between the two study areas. Furthermore, the mean proportion of FCP and DCP contents of the animal showed significant differences ($F_{1\ 15}$ = 35.09, P <0.05) and negatively correlated (Spearman r=–0.242; P>0.05; N=16) in both study areas.

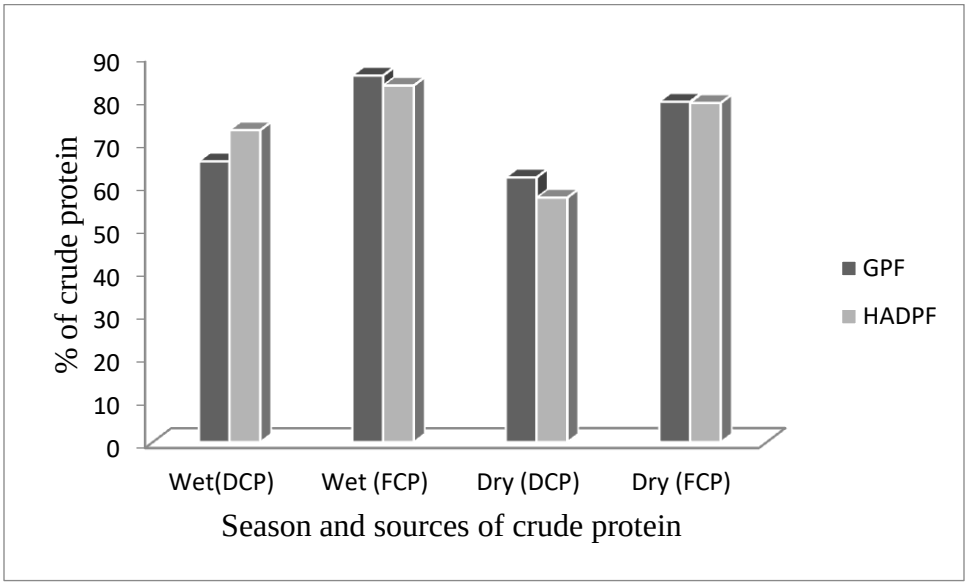


Figure 52. Mean seasonal fecal crude protein (FCP) and dietary crude protein (DCP) contents of common warthogs in GCHA and HADCHA

Neutral detergent fiber (NDF) content of feces of common warthogs was higher inHADCHA (74.28 ± 3.92) than in GCHA (71.01 ± 0.12) and revealed significant variation ($F_{1\ 3}$ = 5.27, P <0.05). On the other hand, NDF content of forage energy consumed by the animals attributed less from GCHA (69.93 ± 4.47) than from HADCHA (71.58 ± 13.62) (Table.34). However, they revealed insignificant differences ($F_{1\ 3}$ = 0.299, P >0.05). The seasonal difference in the mean NDF content of feces and forage energy utilized by common warthogs were not significantly

different (t= 1.09, df=7, P>0.05),butthe NDF contents of feces and forage energy were highly correlated (Spearman r=0.767; P>0.05; N=8).

Acid detergent fiber (ADF) content of feces of common warthogs was higher in HADCHA (59.68 ± 0.03) than in GCHA (55.61 ± 4.96) and showed significant difference ($F_{1\ 3}$ = 6.65 P <0.05). However, ADF content of forage energy consumed by these animals was higher in GCHA (48.37 ± 17.28) than in HADCHA (47.53 ± 15.34) and showed insignificant variation ($F_{1\ 3}$ = 0.04, P > 0.05) (Table 34). Seasonal difference in the mean ADF content of feces and forage energy utilized by common warthogs were significantly different (t= 4.53, df=7, P>0.05).On the other hand, the ADF contents feces and forage energy consumed by common warthogs were highly correlated (Spearman r=0.75; P>0.05; N=8). However, there were no seasonal significant differences between the fecal dry matter and forage dry matter contents of common warthog percentage ($F_{1\ 7}$ = 0.28, P > 0.05) of the two study areas. The seasonal percentage of fecal organic matter and forage organic matter of the two study areas were significantly different ($F_{1\ 7}$= 103.9, P <0.05) (Table 34).

Table34. Fibers measured from feces and diet of common warthog in GCHA and HADCHA

	GCHA		HADCHA	
Nutrients	Wet	Dry	Wet	Dry
Fecal				
DM%	92.83	92.75	92.32	92.11
OM%	76.16	70.64	75.03	75.12
NDF%	71.26	70.77	75.68	72.88
ADF%	54.03	57.18	59.56	59.8
Forage				
DM%	92.23	92.92	92.29	92.02
OM%	90.46	89.26	90.57	87
NDF%	71.43	68.44	74.19	68.97
ADF%	45.43	51.31	44.76	50.3

DM= dry matter, OM= organic carbon, NDF= neutral detergent fiber, ADF= acid detergent fiber

6.6. Threat and status of common warthogs

In GCHA, 39.47% and in HADCHA 42.39% of the respondents realized that common warthog population has declined in the study areas. But, the study areas showed insignificant variation ($\chi 2$ = 0.054, df = 1, P = 0.05) in the number of respondents. In, contrast, 35.52% of GCHA, and 39.13% of HADCHA respondents confirmed that these animals increased in their habitats. However, they revealed insignificant variation ($\chi 2$ = 0.196, df = 1, P = 0.05). On the other hand, 17.1% of GCHA and 7.6% of GCHA respondents noticed no change in the number of common warthog population. Hence, the study areas did not show significant differences ($\chi 2$ = 0.22, df = 1, P = 0.05) in the number of respondents witnessed about the status of the animal. On the contrary, 7.89% of GCHA and 10.86% of HADCHA respondents had no idea about the number

of animals in the study areas. Hence, the study areas were not significantly different ($\chi 2 = 0.15$, df = 1, P = 0.05) (Table35).

Table 35. View of respondents on status of common warthog in GCHA and HADCHA

Study area	Village	View of respondents			
		Increasing	Decreasing	No change	No idea
GCHA	Gassi	12 (15.78%)	17(22.36%)	7(9.21%)	3(3.94%)
	Kodi	15(19.73%)	13(17.1%)	6(7.89%)	3(3.94%)
	Total	27(35.52%)	30(39.47%)	13(17.1%)	6(7.89%)
HADCHA	Chaden	14(15.21%)	21(22.82%)	3(3.26%)	4(4.34%)
	Bareda	22(23.91%)	18(19.56%)	4(4.34%)	6(6.52%)
	Total	36(39.13%)	39(42.39%)	7(7.6%)	10(10.86%)

The three top major threats of common warthogpopulation in GCHA were response to crop raiding 19(25%) followed by habitat degradation11(14.47%) and drought 10(13.15%). The threats in HADCHA confirmed by respondents were response to crop raiding 24(26.08%), followed by predators 15(16.3%) and disease (rinderpest) 13(14.13%). The study areas showed insignificant variationin response to crop raiding ($\chi 2 = 0.285$, df = 1, P = 0.05), habitat degradation ($\chi 2 = 1.52$, df = 1, P = 0.05), drought ($\chi 2 = 0.063$, df = 1, P = 0.05), predation ($\chi 2 = 1.18$, df = 1, P = 0.05) and in disease affecting common warthogs ($\chi 2 = 2.21$, df = 1, P = 0.05) (Table36).

Table 36.Opinion of respondents as major threats of common warthog in the study areas

Study site	Major threats								
	Predators	Domestic hunting	Sport hunting	Drought	Shortage of food	Sho. of water	Disease	Habitat degrada	Resp. C raiding
Gassi	5 (6.57%)	6(7.89%)	2(2.63%)	4(5.26%)	3(3.94%)	1(1.31%)	3(3.94%)	5(6.57%)	10(13.15%)
Kodi	2(2.63%)	3(3.94%)	3(3.94%)	6(7.89%)	5(6.57%)	1(1.31%)	2(2.63%)	6(7.89%)	9(11.84%)
Total	7(9.21%)	9(11.84%)	5(6.57%)	10(13.15%)	8(10.52%)	2(2.63%)	5(6.57%)	11(14.47%)	19(25%)
Chaden	7(7.6%)	3(3.26%)	4(4.34%)	6(6.52%)	2(2.17%)	2(2.17%)	3(3.26%)	2(2.17%)	13(14.13%)
Bareda	8(8.69%)	1(1.08%)	5(5.43%)	5(5.43%)	1(1.08%)	1(1.08%)	10(10.86%)	8(8.69%)	11(11.95%)
Total	15(16.3%)	4(4.34%)	9(9.78%)	11(11.95%)	3(3.26%)	3(3.26%)	13(14.13%)	10(10.86%)	24(26.08%)

Respondents whose crops were not raided by the common warthogshad positive attitude whereas those whose crops were raided by the warthogshad negative attitude towards common warthog population. Respondents of GCHAhad more negative attitude (80.26%) than in HADCHA (76.08%). They were not significantly different($\chi 2 = 0.197$, df = 1, P = 0.05). In contrast, respondents had more positive attitude in HADCHA (15.21%) than in GCHA (13.15%). But they did not reveal significant variation ($\chi 2 = 3.7$, df = 1, P = 0.05) (Table 37).

Table 37. Attitudes of respondents towards the presence of common warthog population in the study areas

Study area	Village	Attitudes of respondents		
		Positive	Negative	No idea
GCHA	Gassi	6(7.89%)	32(42.1%)	1(1.31%)
	Kodi	4(5.26%)	29(38.15%)	4(5.26%)
	Total	10(13.15%)	61(80.26%)	5(6.57%)
HADCHA	Chaden	3(3.26%)	34(36.95%)	5(5.43%)
	Bareda	11(11.95%)	36(39.13%)	3(3.26%)
	Total	14(15.21%)	70(76.08%)	8(8.69%)

In GCHA, 46.05% and in HADCHA 65.21% of the respondents observed that the level of crop damage by common warthog population was very high. But, the study areas showed insignificant variation ($\chi 2 = 1.68$, df = 1, P = 0.05) in the number of respondents. On the other hand, 50% of GCHA, and 23.91% of HADCHA respondents confirmed that the damage was high. However, they revealed insignificant variation ($\chi 2 = 1.15$, df = 1, P = 0.05). In contrast, 3.94% of GCHA and 10.86% of GCHA village respondents witnessed that the crop damage caused by common warthog was insignificant ($\chi 2 = 1.31$, df = 1, P = 0.05). None of the respondents of the two study areas witnessedno crop damaged by common warthog (Table 38).

Table 38. View of respondents on the level of crop damage by common warthog in the study areas

Study area	Village	Level of crop damage			
		Very high	high	Insignificant	No damage
GCHA	Gassi	20(26.31%)	17(22.36%)	2(2.63%)	0%
	Kodi	15(19.73%)	21(27.63%)	1(1.31%)	0%
	Total	35(46.05%)	38(50%)	3(3.94%)	0%
HADCHA	Chaden	26(28.26%)	13(14.13%)	3(3.26%)	0%
	Bareda	34(36.95%)	9(9.78%)	7(7.6%)	0%
	Total	60(65.21%)	22(23.91%)	10(10.86%)	0%

In GCHA, 76.31% and in HADCHA, 63.04% of village respondents thought that conservation action for common warthog was not important in the study areas with insignificant variation ($\chi 2 = 0.87$, df = 1, P = 0.05). In contrast, 27.17% of HADCHA and 11.84% of GCHA respondents believed that protection action of the animals is required in the study areas. However, the study areas did not reveal significant variation ($\chi 2 = 1.24$, df = 1, P = 0.05). On the other hand, 13.15% of GCHA and 9.78% ofHADCHA respondents had no idea about the conservation action of common warthogs in the study areas. But, the study areas showed insignificant variation ($\chi 2 = 2.57$, df = 1, P = 0.05) (Table 39).

Table 39. Opinion of respondents on the need of common warthogs conservation action in the study areas

Study area	Village	Importance of conservation action		
		Yes	No	No idea
GCHA	Gassi	3(3.94%)	28(36.84%)	8(10.52%)
	Kodi	5(6.75%)	30(39.47%)	2(2.63%)
	Total	9(11.84%)	58(76.31%)	10(13.15%)
HADCHA	Chaden	15(16.3%)	23(25%)	4(5.26%)
	Bareda	10(10.86%)	35(38.04%)	5(5.43%)
	Total	25(27.17%)	58(63.04%)	9(9.78%)

7. DISCUSSION

Population abundance

Population size estimates are fundamental for understanding the species entire ecology, offering credible information on fluctuation in size and enabling monitoring of population trends (Young *et al.,* 2009). Hence, reliable estimation on population size represents an essential step in monitoring the cost of population management activities (Msoffe *et al.,* 2009).Likewise, using fixed half–width of strip line transect method, the present study estimated more mean number of common warthog population per transect during the wet season and during dry seasonsin HADCHA. On the contrary, the mean number of common warthog population in GCHA was lower per transect during the wet and during the dry seasons than HADCHA. This might be due to enhanced habitat suitability and forage availability that attracted common warthog populations more to HADCHA than GCHA. However, the finding of the present study was contradicted with Thorp, (2012), who found small mean number of common warthog populationin Maasai Mara National Reserve and in the adjoining group ranch, Koyake GR, in south–western Kenya (1.645±2.389 per transect).

Group size is vital for precise estimation of wildlife population abundance (Msoffe *et al.,* 2009). It is influenced by availability of food, predation and deforestation pressures. Predation, timing of the reproductive cycle and number of young born also put their impact on population group size (Patry *et al*., 1995). It could be an indication of habitat quality where they live socially in harmonious ways (Mattiello *et al*., 2004). The mean cluster size ofcommon warthog population recorded in HADCHA was higher than in GCHA. Simultaneously, higher MOCS and MECS common warthog population were recorded in Gimbicho and Dodeta of the HADCHA. In

general, MOCS and MECS of the animal were greater during the dry season than during the wet season in both study areas. This could be due to more reproductive facility and feeding accessibility in HADCHA than in GCHA. Conflict between common warthog group members and the demand for preferred habitats and strangers also ultimately determine a compromise group size of common warthogs population (White, 2010). The finding of the present study was comparable with White (2010), who observed the mean cluster size ofcommon warthog populations (1–8) in the iMfolozi Game Reserve, KwaZulu–Natal Province of South Africa.However, the present study contradicted with Apio *et al.*,(2015), who found lower mean common warthog cluster size in Akagera National Park of Rwanda (2010= 3.6), (2011=2.9), (2012= 3.9) and (2014= 3.7), conflicted with Cunninghad(2013), who observed lower mean common warthog cluster size innorth–central Namibia 2.2 and 1.3 during the wet and dry seasons, respectively.

The quality and quantity of resources, both abiotic and biotic factors that are available for ungulates at different scales of time will influence their distribution and abundance patterns (Gautam, 2013). The present study estimated higher common warthog population abundance in HADCHAthan in GCHA.The highest population abundance of common warthog was recorded from HADCHA study sites of Desa and Dodeta during the wet season whereas the maximum population abundance estimate of common warthog were also observed in HADCHA study sites of Gmbicho and Desa during the dry season. This might be due to more resource availability and habitat suitability in HADCHA than GCHAfor common warthog population occurrence. The finding of the present study was comparable with the Bale Mountains National Park assessment (W=536, D=616) (Ermias Deribe, 2001). However, the finding of the present study was

higherthan the value estimated in Diregudo Forest of Gololcha of southeast Ethiopia (W= 50, D=41) (Abdulfatah Abdu and Demeke Datiko, 2017) andin Mkwaja North (20) and in the Saadani Game Reserve (151) of Tanzania (Treydte, 2004). The finding of the present study was lower than the value estimated in Kruger National Park of South Africa (2000 to 5000individual common warthogs) (Swanepoel *et al.,* 2016), in Nazinga Game Ranch of Burkina Faso 2411 common warthog (Marchal *et al.,* 2012) and 1494– 5724 (Hema *et al.,* 2017), in north–central Namibia 7125 and 1075 individual warthog during the wet and dry seasons, respectively (Cunninghad, 2013).

Estimating population density of an animal in certain area is a basic tool to understand its status, demography and plan for its management and conservation (Varmanand Sukumar, 1995). Likewise, in the present study, the highest common warthog cluster density was observed in Gimbicho and Dodeta study sites of HADCHA. This could be due to better monitored controlled hunting area by local guards and frequent visitation of Woreda and zone officers in HADCHA than in GCHA. The present density estimate of common warthog was consistent with values estimated in protected areas of central Kenya (1–10 animals/km²) (de Jong *et al.,* 2016), in Nazinga Game Ranch of Burkina Faso (2.41 individuals/ km² and CV=32.6%) (Marchal *et. al.,* 2012) and in north–central Namibia 4.05/km^2 during summer and 1.95/km^2 (Cunninghad, 2013).Others studies estimated the density of common warthog lower value than the present study in Akagera National Park of Rwanda (in 2010; 0.09/km^2 and CV=51.9%), (in 2011; 0.14/km^2 and CV=48%), (in 2012; 0.12/km^2 and CV=58.6%), and (in 2014; 0.25/km^2 and CV=56.7%) (Apio *et al.,* 2015) and in Selous Game Reserve of Tanzania (1.7/ km^2 with 95% CI: 1.5–1.8) (Creel *et al.,* 2018), in *Acacia* bushland habitat at Mpala Research Center of Kenya (0.19 /km^2, CV=29.27% with 95% 0.62–0.58) (Augustine, 2010). However, it was smaller than

the values reported elsewhere in short grass of Nakuru National Park of central Kenya (77 animals/km²) (de Jong *et al.,* 2016) and in the iMfolozi Game Reserve, KwaZulu–Natal Province of South Africa (26.0/km^2 in 2006) and (22.8/km^2 in 2007), (White, 2010; Swanepoel *et al.,* 2016).

Population abundance and density estimation of animals are primarily based on sightings and culling of the favorite animal in particular habitats (Keeping and Pelletier, 2014). Hence, in the present study, comparable clusters of common warthog sightings were recorded from both study sites duringboth seasons. This might be due to similar physical futures of DVF in both controlled hunting areas. The finding of the present study was similar with Apio *et al.* (2015), who found (26 sightings) in Akagera National Parkin Rwanda. The findings of other studies recorded common warthog population sightings lower value than the present study during different study periods in Akagera National Park of Rwanda (9in 2010), (14 in 2011) and (12 in 2012) (Apio *et al.,* 2015), in Burunge wildlife management areas of Tanzania (4) (Lee, 2018). On the other hand, more sightings of warthogs recorded than the present study in the iMfolozi Game Reserve, KwaZulu–Natal Province of South Africa (109–231 common warthog sightings) during different periods of the year (White, 2010).

Encounter rateis discrete events between the researcher and the targets, which are distributed with a specific geometry in space and time and it is essential to many ecological processes (Msoffe *et al.,* 2009; Gurarie and Ovaskainen, 2012). During the present study mean encounter rateof common warthog population of both study areas were comparable. This could be due tothe encounter rates of common warthog population of both study areas were related to their transect

width and length. Hence, the highest and lowest encounter rate and random movements of the animals were similar in both study areas.

Detection function is used to infer how many animals are missed and thereby produce estimates of population size and density of spatially clustered species efficiently (Burnhad*et al.,* 1980; Msoffe *et al.,* 2009). During the present study, the MDP of common warthog population in both study areas showed parallel finding. This might be due to the lower proportion in GCHA and high proportion in HADCHA of the animals was potentially equal probability of detection.

The cost and benefits of grouping of individuals are mainly reliant on the amount of the groups with average individual fitness maximized at an optimal group size. The distribution of group size depended on the age and sexof the animals in a particular habitat (White, 2010). In the present study, HADCHA comprised all sounders of common warthog population larger size than GCHA. This might be due to low resource competition, anthropogenic pressure, and predation risk in HADCHA than in GCHA. But, other studies found common warthog groups' size lower value than the present study in Diregudo Forest of Gololcha of southeast Ethiopia (Adult male=17), (Adult female=25), (sub–Adult male=13), (sub–Adult female=21), and (unidentified juvenile sex=15) (Abdulfatah Abdu and Demeke Datiko, 2017), in iMfolozi Game Reserve (iGR) in the KwaZulu/Natal Province of South Africa (Adult female=107) and (Adult male=92). The finding of (unidentified juvenile sex =505) in iMfolozi Game Reserve (iGR) in the KwaZulu/Natal Province of South Africa was higher than the finding of the present study (White, 2010).

During the present study, unidentified juvenile sex followed by sub–Adult male and females formed the highest common warthog population in the study areas during both seasons. The finding of the present study was consistent with the valueof sub–Adult female (23.08%), higher than unidentified juvenile sex(16.48%) and sub–Adult male (14.29%) and lower than Adult female (27.47 %) and Adult male (18%) common warthog population groups observed in Diregudo Forest of Gololcha of southeast Ethiopia (Abdulfatah Abdu and Demeke Datiko, 2017). Likewise, the finding of the present study was comparable with (Adult male=13%) and (Adult female=15.2%) and higher than (unidentified juvenile sex =71.73%) recorded in iMfolozi Game Reserve in the KwaZulu/Natal Province of South Africa (White, 2010). In the present study, the number of Adult male and sub–Adult male of both study areas,unidentified juvenile sex in GCHA and sub–Adult female common warthog population groups in HADCHA were not influenced by season. In contrast, the number of Adult female in both study areas and sub–Adult females in GCHA and unidentified juvenile sex common warthog populations in HADCHA were influenced by season and significantly larger during the dry season than the wet season. Adult female common warthogs group was related to changes in environmental variables and costs of reproduction during wet season (White, 2010). The finding of present study was comparable with iMfolozi Game Reserve in the KwaZulu/Natal Province of South Africa thatthe number of Adult male and unidentified juvenile sex were not influenced by season whereas the number of Adult females was affected by seasonal variation(White, 2010).

Habitat association

Knowledge about the association between animals and their habitats with the resources is essential to conceptualize behavior and space use. For some animal population, this is particularly important because habitat loss or fragmentation threatens their survival (Bjørneraas,

2011).The present study has revealed thatthe mean number of common warthog population in *Combretum–Terminalia* habitat,riparian forest and open grasslandinGCHA was lower than in HADCHA.This could be due to large number of human encroachment in the buffer zone of GCHA than in HADCHA. Okello (2012) observed less abundance of warthogs sounder size in Mbirikani group ranch in the Amboseli ecosystem of Kenya in different habitats

Animals use habitat to acquire food, water, cover, space, refuge and ambient temperature (Kahana *et al.,* 2013). The process of habitat selection determines how animals are dispersed in space and time, with consequences for population dynamics and interspecific interactions (van Beest *et al.,* 2013).During the present study, comparable proportion of common warthog population was recorded in each similar habitatsof both study areas during both seasons. This might be due to homogenous habitat and structure types of Dabena Valley Forest in both study areas. The findings of the present study were lower than the proportion of common warthog population in grassland (47.25%), but higher than the proportion in savanna woodland (21.98%)of Diregudo Forest of Gololcha, southeast Ethiopia (Abdulfatah Abdu and Demeke Datiko, 2017). On the other hand,the number of common warthog populationin *Combretum–Terminalia*habitat was higher than in riparian forest andin open grassland in HADCHA and GCHA. This could be due to diversified food supply and better cover facilities in *Combretum–Terminalia* than in riparian forest and open grassland habitats. The finding of the present study was consistent with Kahana *et al.* (2013), who found 81 common warthog population in open grassland habitat of Mount Meru Game Reserve, Tanzania. However, it wascontradicted with Abdulfatah Abdu and Demeke Datiko (2017), who observed lower number in open grassland (24 and 19) and in savanna woodland (11 and 9) common warthog populations during the wet and

dry seasons,respectively. The finding of the present study does not go in line with the study of, Okello (2012), who found small and variable number of common warthog populations in Mbirikanigroup ranch of the Amboseli ecosystem of Kenya.Rabira Gonfa *et al.,* (2015), observed smaller number; in savanna woodland 16, in grassland 15 and in riparian 3 common warthog populations in Dati Wolel National Park, Western Ethiopia.

The distribution of mammalian species within the area, and their relative abundance across different habitat types are the significant knowledge essential for effective management of mammals (Sathyakumar *et al.,* 2011). Higher population abundance of common warthogs was estimated in the *Combretum–Terminalia* habitats, riparian forest and open grassland habitat inHADCHA than in GCHA. This might be due to the frequent human activities observed in and around the buffer zone of the entire habitat types, for honeybee production and chopping treesin GCHA than in HADCHA.

During the present study,*Combretum–Terminalia*habitat, riparian forest and open grassland habitathosted moremean common warthogs cluster density in HADCHA than in GCHA during the wet and dry seasons. This could be due to high resource availability and lower human disturbance in HADCHA than in GCHA. Moreover, seasonal variation in resource availability and other environmental conditions help animals to determine which habitat types to be used (Borger *et al.,* 2006). *Combretum–Terminalia* habitat had the highest cluster density of common warthog population during the dry season, followed by open grassland and riparian forest.Common warthog population density in Diregudo Forest of Gololcha was higher than the

finding of the present studyin grassland (13.44/km²) and comparable with the present finding in savanna woodland (5.65/km²) (Abdulfatah Abdu and Demeke Datiko, 2017).

During the present study, both study areas had comparable common warthog sightings in all habitats.. This could be due to uniform spatial organization of common warthog population in the entire habitats of the study areas and the sighting events of the animal in the habitats showed similarity. However, *Combretum–Terminalia* had the highest common warthog sightings, followed by open grassland and riparian forest.

Encounter rate is a dynamic, stochasticprocess that explicit in space, time and account for changing the animals' spatial distributions in different habitats and their temporal scales(Gurarie and Ovaskainen, 2012). During the present study, both study areas had consistent common warthog encounter rate in all habitat types. This could be due to the similarity behavioral movement, spatial distribution and birth–deathdynamics of the common warthog population in the habitat (Gurarie and Ovaskainen, 2012). In contrast, the encounter rate of common warthog in open grassland was higher in HADCHA and lower in GCHA during the wet season. This might be due to sharing of resources by cattle and common warthog and the nearness of farming activities to this habitat more in GCHA than in HADCHA. On the other hand, during the present study, MDP of common warthog population inthe three habitats showed insignificant variation during the wet and dry seasons in both study areas. This might be due tothe tactic of hidings from the radial distance and pattern of movement of the animal in all habitats showed similarity.

Diurnal activity patterns

The activity pattern of a species is a significant characteristic of its ecology and physiological factors that reflect ecological interactions. Endogenous biogeochemical processes maintained the activity pattern of most species, which is stimulated by cyclical environmental variations, such as the daily photoperiod (Streicher *et al.,* 2017; Leuchtenberger *et al.,* 2018). Hence, the upper limit on how much time a large mammalian herbivore can devote to foraging is set by thermal stress. Foraging increases heat loAM of the animal through muscular activity and exposure to direct and indirect solar radiation (Owen–Smith, 1998). Hence, during the present study, the mean time of AF and AM common warthogs engaged in feeding peaked in the morning and afternoon time blocks in GCHA. However, in HADCHA the mean time of AF and AM common warthog spent in feeding was highest in the morning time block. This could be associated with lower ambient temperatures during the morning and afternoon time blocks (Shannon *et al.,* 2008). The finding of the present study was similar with previous study conducted in the Bale Mountains National Park, Ethiopia (Ermias Deribe *et al.,* 2008). On the other hand, the mean time of AF and AM common warthog involved in feeding was not influenced by season. This might be due to both sexes exhibiting similar patterns of feeding behavior during both seasons. During the present study, there was no significant variation between GCHA and HADCHA in mean duration of time both sexes spent for feeding during both seasons. This might be due to the pattern of feeding was very similar across the study areas and both sexes increased mean duration of time allocated for feeding to meet their daily energy requirements.

Ungulates of any body size usually seek shade at the most demanding times of the day and significantly reduce their overall daytime activity. Resting showed a strong inverse correlation

with feeding and walking (Shannon *et al.,* 2008). Common warthogs seek shade during the midday time block. They usually lack significant dermal fat, which facilitates heat dissipation (Vercammen and Mason, 1993). This species show low resistance to cold and they raise body temperature by sheltering in burrows and clustering together by constructing grass nests (Vercammen and Mason, 1993). During the present study, the mean time of AF and AM common warthogs engaged in resting was highest during the midday time block in both study areas during the wet and dry seasons. This might be to lower their basic metabolic rate and to conserve energy (du Toit and Yetman, 2005; Mahenya, 2016). The present study was consistent with the findings in the Bale Mountains National Park, Ethiopia (Ermias Deribe *et al.,* 2008). The mean time of AF and AM common warthogs engaged in resting was not impacted by season. This might be due to both sexes becoming equally sensitive to extreme high temperature and showing comparable patterns of resting behavior during both seasons. Moreover, there was no significant variation between GCHA and HADCHA in the mean duration of time AF and AM spent for resting during both seasons. This might be due to uniform the daily ambient temperature of DVF in GCHA and HADCHA.

Ungulates engaged in more walking when food availability is scarce or when food sources patchily dispersed, thus more time is required for walking and searching for food (Mahenya, 2016). On the other hand, warthogs often walk away to avoid humans passing and on detecting predators (Hjertlöv, 2015). During the present study, the mean time of AF and AM common warthog embarked on walking was highest in the afternoon block in both the study areas during the wet and dry seasons. This might be due to environmental factors playing a greater role in dictating this diurnal activity pattern (Owen–Smith, 1998). Warthogs also walked longer time in

the afternoon time block to find their den. The mean time AF and AM common warthog engaged in walking was influenced by season and it was greater in the dry season in GCHA. In contrast, the mean time AF and AM common warthogswalked was not subjected by season in HADCHA. This could be due to shortage of food during the hottest period in GCHA than in HADCHA. Hence, both sexes of common warthog walked more in search food during the dry season in GCHA than in HADCHA. There was no significant variation between GCHA and HADCHA in the mean duration time that AF and AM spent for walking during the wet season. But, AF and AM common warthogs took more time to walk in GCHA than in HADCHA during the dry season. This might be due to more time took for walking for food when biomass and quality of the ingested food decline during the dry season (Owen–Smith, 1998).

Vigilance requires limited resources such as time and visual attention (Altmann, 1974). Hence, vigilance conflicts with other behavioral activities, like feeding, resting, salt licking and wallowing (Treves, 2000). It occurs in response to external stimuli (Owen–Smith and Traill, 2017). In the present study, the mean time AF common warthogs engaged in vigilance was highest in the morning time block during the dry season and peaked in the afternoon time block during the wet season in GCHA. Similarly, AM common warthog of both study areas and AF of HADCHA involved in vigilance more in the afternoon time block. This could be due tomore time spent for foraging in the morning time block, which is accompanied by simultaneous reduction in one or more other activities, such as vigilance, walking and resting (Worsley–Tonks and Ezenwa, 2015). They often practiced apprehension behavior in the morning time block. Unlike vigilance, apprehension allows animals to search food while it is more alert for predator risk (Hochman and Kotler, 2007). Animals reduce feeding cost or sacrifice feeding effort in the

afternoon time block to increase vigilance for predation risk (Cleveland, 2010; Simpson *et al.*, 2012). Treves (2000) reported that strategies in animals for allocation of time and effort to vigilance are expected to vary with group size and the behavior of associates. On the other hand, during the present study, the mean time AF of both study area and AM of HADCHA engaged in vigilance were impacted by season. In contrast, the mean duration of time AM common warthogs took part in vigilance was subjected by season, and it was greater during the dry season. This might be due to vigilance was highest in predation risk area. Females have greater energy requirements for their offspring and themselves to prioritize foraging and they benefit from the presence of vigilant males (Treves, 2000; Simpson *et al.*, 2012).

The need of salt in mammals exhibited primarily in spring and summer and attributed to seasonal needs of minerals in response to metabolic acquisition (Risenhoover and Peterson, 1986Nichols, 2012). Ungulates have high inclination for salt, and they are the most frequently encountered species at salt lick sites (Hon and Shibata, 2013). During the present study, the mean duration of time AF and AM warthogs visited saltlick sites peaked in the morning and afternoon time blocks. This finding was similar to the observation on large mammal, inside Kainji Lake National Park, Nigeria (Ajayi and Ogunjobi, 2015). This could be connected with feeding effort peak hours of the day and make easy the gastrointestinal issues and buffers the effects of dietary toxins (King *et al.,* 2016). On the other hand, during the current study, the mean time AF of both study areas and AM of GCHA engaged in salt licking wasinfluenced by season. This might be due to the reproductive activity of AF pushing to salt lick sites higher than their male counterparts do in the study areas (Ping *et al.*, 2011; Ajayi and Ogunjobi, 2015). In the present study, there was no significant variation between GCHA and HADCHA in mean the duration of time AF and AM

spent for salt licking. This might be due to comparable warthog attraction of licking sites in the study areas.

Common warthogs lack functional sweat glands. Hence, they wallow in the mud to lower their body temperature.Wallowing also servesto combat ectoparasites by rubbing against trees (Allwin *et al.,* 2016). Wallowing triggers sexual attraction and has scent marking functions. The mean duration of time AF and AM common warthogs wallow in mud was higher in the afternoon time blocks in both study areas. This might be associated with relatively low ambient temperatureduring the afternoon time block (Huynh and Aarnink, 2005), and wallowing behavior was dictated by environmental factors (Shannon *et al.,* 2008). Hence, common warthog body temperatures fluctuate within a certain tolerance range and cope with high temperatures by behavioral strategies of wallowing (Ermias Deribe 2001; Swanepoel *et al.*, 2016). This finding was in agreement with Ermias Deribe(2001), who conducted similar study in the Bale Mountains National Park, Ethiopia. On the other hand, during the present study, the mean time AF of both study areas and AM of HADCHA engaged in wallowing varied based on season. Wallows are used frequently during the summer months when animals behaviorally try toreduce their heat loAM and for thermoregulation (Allwin *et al.,* 2016). In the present study, there was no significant variation between GCHA and HADCHA in the mean duration of time AF and AM allocated for wallowing during both seasons. This might be due to insignificant variation of weather conditions in the present study areas.

Environmental, ecological and social factors influence how much time animals allocate to different behaviors (Worsley–Tonks and Ezenwa, 2015). Herbivores spend majority of their daily time for feeding effort (Ryan and Jordaan, 2005; Owen–Smith *et al.,* 2010). During the present study, Adult common warthog population allocated the highest proportion of daytime for feeding activity. This could be associated with the energy maximizing strategy of the animal. This finding the present study was in line with Ermias Deribe (2001), who studieddiurnal activity patterns of common warthog population in the Bale Mountains National Park, Ethiopia. In the present study, resting was the second important diurnal activity pattern of warthog and it was consistent with the finding of Ermias Deribe (2001). This might be due to the natural response to extremely high ambient temperatures of the study areas. Walking is energyconsuming activity of animals (Shannon *et al.,* 2008). However, in the present study, it was the third prominent activity warthogs. This finding was in agreement with the study of Ermias Deribe (2001). This might be due to walking increased searching food in the study areas.

Feeding ecology

The way animals make use of their environment, particularly the kinds of food they consume and the habitats where they occupy are central elements to the study of animal ecology and management (Macleod *et al.,* 1996). Epidermal fragments in feces and direct observation of foraging animals (Henley *et al.,* 2001; Zweifel–Schielly *et al.,* 2012) determine diet composition of a given animal.Common warthogs forage on a wide range of food resources with high nutrient levels (Mgqatsa, 2010). Therefore, in the present study, feeding quadratsurvey revealed graminoids, herbs, shrubs and climbersin the feeding station of common warthog population in GCHA and HADCHA. The diet composition of common warthog population observed in the leaf cuticle fragments of feces was similar across both study areas during the wet and dry

seasons. Likewise, comparable number of plant species identified as annual dietary composition of common warthog in GCHA and HADCHA. This might be due to the plant composition andstructuresthat attracted the animals did not show variation between the study areas. The present study was in agreement with Mgqatsa (2010), who found 42 forage species in the Addo Elephant National Park of South Africa. In contrast, the current study was inconsistent with Treydte *et al,* (2006), who identified 63 plant taxa as annual dietary composition of common warthog in formercattle grounds of Tanzanian savanna, which was higher than the finding of the present study. Other studies identified small number; 22 plant species that common warthogs consumed in Bale Mountains National Park (IUCN SSC, 2012), ninteen forage species of grasses in the AddoElephant National Park of South Africa (Mgqatsa, 2010). In the present study, graminoids, comprised the largest identified forage species of common warthogs, followed by herbs and shrubs. This could be due to the high palatability of graminiods and nutrient-rich plant species (Treydte *et al.*, 2006).

Common warthogs areselective in their forage in a savanna landscape to realize their nutrition requirements and go for patches of high quality grasses, particularly when there is nutrient shortage during the dry season (Treydte, 2004). Hence, warthogs are recognized as committed grazers (White, 2010; Hjertlöv, 2015) because they have unique multi–cusped hypsodont third molar and reduced premolars that are well Adapt to grazing (Mgqatsa, 2010).In the former rangeland of Mkwaja North of Tanzania, 77% common warthog diet was covered by grass and in the former Saadani Game Reserve, Tanzania, grass contributed 98 % of the animals diet (Treydte, 2004). On the other hand, grasses formed 87.4% of common warthog diet in the Addo Elephant National Park of South Africa. Other study also found 64% of common warthog diets were contributed by grass species in Kichwa Tembo, Kenya (Hjertlöv, 2015). Similarly, in the

present study, the annual diet composition of common warthog constituted by grass was comparable in GCHA and in HADCHA. They also include some browse such as woody shrubs, herbs and fallen fruits in their diet (Treydte *et al.,* 2006; Mgqatsa, 2010).Other study also observed common warthog consumed herbs in Mount Meru Game Reserve, Tanzania (Kahana *et al.,* 2013), in Kichwa Tembo, Kenya herb (Hjertlöv, 2015) and in the Addo Elephant National Park of South Africa as diet of the animal (Mgqatsa, 2010). In the present study, herbs contributed common warthog annual diet in GCHA and HADCHA.

Herbivores consume different plant species to balance their nutritional requirements and avoid over ingestion of toxic plants and secondary compounds (Belovsky, 1984). High quality forage species are often preferred by large herbivores (Dumont, 1997). Hence, epidermal plant fragments in feces frequently quantified on microscopic slide during microhistolological analysis reveal which plant species abundantly consumed and preferred by animals (Johnson *et al.,* 1983). During the present study, *C. nlemfuensis, C. dactylon,H. rufa, C. fischerianus*and*A. abyssinicus*in both study areas*B. Ethiopum* and *D. abyssinica* in GCHA were the most frequently consumed forage species of common warthogs. This could be due to better vision against of potential predators while grazing these short grasses (Treydte, 2004; Thorp, 2012). Warthogs' front knees are padded and morphologically Adapted to graze short grasses by kneeling down on their front legs (Thorp, 2012; Hjertlöv, 2015). Warthogs are also attracted to short grasses because they get high nutritional concentration from such grasses (Treydte *et al.,* 2004; Thorp, 2012). Many foraging species recorded in the present study have not previously reported as dietary composition of common warthogs across the range of the species. These include, *D. abyssinica, H. hirta, H. cymbaria, H. varibilis, P. nubicwn, P. clandestinum, P. purpureum, M. repen, S.*

poiretiana, S. polystachya, and *A. abyssinicus.* This might be due to variation in the forage species of common warthogs between seasons and habitat types across the range of the animal (Treydte, 2004).

Diet composition of herbivores also show which forage species are specifically selected as a staple dietary item in a given season. A staple dietary item is a forage species that contributed 3% or more to the diet of the animal during the foraging period (Petrides, 1975; Tshabalala *et al.,* 2009). Similarly, during the present study, comparable annual staple forage species were identified in GCHA and HADCHA. Other study found fifteen staple dietary items of common warthogs in the Addo Elephant National Park of South Africa (Mgqatsa, 2010), which was higher than the present study.*Cyodon dactylon*was the most prominent staple food of common warthogin Mount Meru Game Reserve in Tanzania (Kahana *et al.,* 2013) and in Mkwaja Ranch of Tanzanian (Treydte *et al.,* 2006). It was also identified as staple food in the former Saadani Game Reserve of Tanzania (Treydte, 2004), in the Maasai Mara National Reserve in Kenya (Thorp, 2012) and in the Addo Elephant National Park in South Africa (Mgqatsa, 2010). *Digitaria ciliaris* and *Sporobolus* spp were reported as major food source of warthogs in Mount Meru Game Reserve in Tanzania (Kahana *et al.,* 2013). *Cyperaceae* sppand *Panicum* spp formed greater contribution to warthog diet in Mkwaja Ranch in Tanzanian (Treydte *et al.,* 2006) and the later forage species in the Maasai Mara National Reserve in Kenya (Thorp, 2012).

In the present study, two perennial staple grasses such as *C. nlemfuensis* and *C. dactylon* and the annual staple grass; *H. rufa* formed major plants of common warthog diet in GCHA and

HADCHA during both seasons. This might be due to large quantity utilization of these forage species during the wet and dry seasons. During the late dry season, *H. rufa*was regenerated following the savanna fire and consumed in larger amount. On the other hand, *C. dactylon*is drought resistant species and *C. nlemfuensis* occur under the shade of woody plant and riparian forest areas during the dry season. *Hyparrhenia rufa* hasalso been reported as the major food of the animal inMkwaja Ranch in Tanzanian (Treydte *et al.,* 2006).Unlike *C. dactylon*and*H. rufa, C. nlemfuensis* has not been reported in any one of the previous studies as staple food of common warthogs across the ranges of warthogs (Treydte, 2004; Treydte *et al.,* 2006; Mgqatsa, 2010;Thorp, 2012; Kahana *et al.,* 2013; Hjertlöv, 2015). In the present study, the proportion of *C. nlemfuensis,C. dactylon* and *H. rufa* in the diet of common warthog was higher during the wet season than during the dry season. This could be due to young, fresh and green foliage of these species usually attracting common warthogs grazing during the wet season than during the dry season (Owen–Smith, 1998; Thorp, 2012).

Availability of palatable forage specieshas an important effect on the diet preference of animals and permit animals to select a wider range of plant species with little or no risk of nutritional stress (Zweifel–Schielly *et al.,* 2012). Decrease in the availability of forage species results in the use of less desirable forage species (Anderson *et al.,* 2010), which elevate metabolic costs of locomotion and limits survivorship of the animal (Hanleyand McKendrick, 1983). In the present study, comparable seasonally available forage species, which contributed ≥1% in the diet of common warthog were identified in GCHA and HADCHA during the wet and dry seasons. *Cyodon nlemfuensis*, *H. rufa*, *H. hirta*and *C. dactylon* are the most available forage species of the study areas. On the other hand, *Eragrostis* spp in HADCHA and*D. Abyssinica* in GCHA were the

most available forage species during the wet and dry seasons. *Cyodon dactylon* and *Eragrostis* spp were also particularly abundant in the diet of common warthogs in Mkwaja Ranch in Tanzanian (Treydte *et al.,* 2006).

Herbivores usually accept new food that is nutritionally complementary to that recently eaten and foraged fresh food that lack secondary metabolites (Singer *et al.,* 2002; Jr *et al.,* 2008; Muir*et al.,* 2015; Chinomona *et al.,* 2018). They ignore nutritionally unbalanced food and leave food after excessive exposure to toxic or deterrent effects of particular secondary metabolite (Dearing *et al.,* 2005; Owen–Smith *et al.,* 2010; Kohl *et al.,* 2014). In the present study, *C. fischerianus,D. abyssinica, C. dactylon, C. nlemfuensis, H. rufa,* and*A. Abyssinicus* were highly preferred by common warthogs in both study areas during wet and dry seasons. *Panicum maximum,P. nubicwn* and *S. sesban* had moderate acceptability index in both study area during the wet season. *Hyparrheniarufa* and *B. ethiopum* in GCHA *Eragrostis* spp *H. varibilis* and *F. sur* in HADCHA had moderate acceptability index during the dry season. *Borassus aethiopum,* and *C. benghalensis* during the wet season and *H. hirta, F. sycomorus* and *F. vasta* during the dry season had low preference by common warthog in both study areas.

Salt or mineral lick influences the movements and distribution of ungulates (Ayotte *et al.,* 2008) and physiologically against intestinal ailments associated with forage phenology and serve to supplement mineral intake (Ayotte *et al.,* 2008; King *et al.,* 2016). It also maintains the equilibrium between the major minerals in the body of herbivorous mammals (King *et al.,* 2016). On the other hand, energetic costs to seek out mineral licks reduce time for foraging on vegetation (Klaus *et al.,* 1998). Mineral elements are deficient in the diet of ungulates (Ayotte*et*

al., 2008). Similarly, common warthogs and other ungulates regularly consume soil in African savannas for seeking different mineral elementsto meet their nutritional requirements (Oliver *et al.,* 1995; Thorp, 2012). Organic carbon buffers against disorders associated with wet season forage change, stabilizing pH in the stomach of ungulates and it is the main source of energy (Klaus *et al.,* 1998; Ayotte, 2004). Likewise, in the present study, common warthogs ingested comparable mean proportion of organic carbon salt lick in GCHA and in HADCHA during the wet season. During the dry season, the mean proportion of organic carbon was lower in GCHA and higher in HADCHA. This might be due to natural licks are special habitat features and site–specific to maintain the health of ungulate populations (Ayotte*et al.,* 2008). The finding of the present study showed differences from Treydte *et al.* (2006), who described (OC=1.2±0.3) ingested by common warthogs in Mkwaja Ranch,Tanzania, was smallert han the finding of the present study.

During the present study, the mean total nitrogen proportion in salt licking common warthog ingested was higher in GCHA and less in HADCHA during the wet season. During the dry season, the mean proportion of total nitrogen was less in GCHA and higher in HADCHA. The finding of the present study was consistent with the finding of Treydte *et al.* (2006), who reported total nitrogen ingested by common warthog in Mkwaja Ranch in Tanzania. Phosphorous is one of the major mineral elements, whichmaintains an animal body (Montenegro, 2004). In the present study, during the wet seasonthe mean phosphorous concentration from salt lick common warthog ingestedwas less in GCHA andmore in HADCHA. During the dry season, the mean concentration of phosphorous in GCHA and in HADCHA was comparable. This could be due totemporal and spatial patterns of licks visiting are different in the study areas and during

season of year (Ping *et al.*, 2011). The finding of the present study was contradictory with Treydte *et al.* (2006), who found lower amount of phosphorous ingested by common warthog in Mkwaja Ranch in Tanzanian.

Na is a key driver of natural lick visitation (Ayotte *et al.*, 2006). During the dry season, grazing animals compensate for low Na concentration by visiting mineral springs, and salt–impregnated soils (Ramachandran *et al.*, 1995; Beck and Peek, 2005). Thus, Na benefits ungulates in osmolarity regulation and compensate seasonal deficiencies in many forage plants (Ayotte, 2004). In the present study, both study areas common warthogs ingested consistent meq/100gof Na in the salt lick during the wet and dry seasons. K ingested from earth licking elevates the osmotic pressure of the digestive tract and interferes with fecal water absorption. This leadsto the loss of potentially harmful electrolyte and regulate acid–base equilibrium in animals (Ramachandran *et al.*, 1995;Ayotte, 2004). Hence, in the present study, the mean K concentration in salt lick common warthog was smaller in GCHA and greater in HADCHA. In contrast, during the dry season, the mean concentration of K ingested from the salt lick was similar in both study areas.

Ca and Mg are motivating factors of natural lick visitation (Ayotte *et al.*, 2006). However, they are extensivelyused by ungulates (Ayotte, 2004). Ca is the major mineral constituent of the animal body (Montenegro, 2004). Mg levels make the forage sub–optimal for maintaining animal growth and body condition (Ayotte, 2004). In the present study, similar mean of Mg and Ca concentration were in salt lick by common warthog in GCHA and HADCHA during the wet

the dry seasons. This might be due toeven distribution of these mineral elements in Dabena Valley Forests.

Nutrient quality

Nutrition directly affects life–history traits, such as survival, fertility, body mass, litter size, longevity, as well as demography and population dynamics of ungulates (Wrench *et al.,* 1997; Owen–Smith, 2002; Gil–Jiménez *et al.,* 2015; Holá, 2016). Hence, determination of nutritional status of animals is significant for wildlife population and habitat management (Wrench *et al.,* 1997; Treydte *et al.,* 2006). Forage quality estimates through fecal analyses and plant materials collected from feeding quadrats were used to determine nutritional status of animals (Holecheck, 1982; Wrench *et al.,* 1997). Therefore, C, P, N, crude protein (CP), fiber content; neutral detergent fiber (NDF) and acid detergent fiber (ADF) in the feces and diet of common warthogs have been used to track changes in diet quality (Treydte *et al.,* 2006; Codron *et al.,* 2007). In African savannas, common warthogs forage grasses (C4 plants) and the non–grass component (C3 plants) to obtain organic carbon (Treydte, 2004; Treydte *et al.,* 2006). In the present study, the amount of dietary carbon that common warthogs consumed was less in GCHA and high in HADCHA during the wet season. On the other hand, the amount of fecal carbon of common warthogs calibrated in GCHA and HADCHA was consistent. Fecal and dietary carbon of these animals was negatively correlated. This might be due to microhistological analyses of feces provided the most detailed information about the plant species that common warthog consumed than plant materials collected from feeding quadrats. The finding of both study areas was consistent with Treydte *et al.* (2006), who reported (fecal carbon= 26%) in Mkwaja Ranch in Tanzania. On the other hand, dietary carbon of GCHA was comparable with Treydte *et*

al.,(2006), who measured (dietary carbon= 9.8%) and Clauss *et al.*, (2008) who calibrated (dietary carbon=9.3%) for captive common warthog at Rotterdam Zoo. Hence, fecal carbon calibrated showed that the animals did not suffer from shortage of dietary carbon in both study areas (Treydte, 2004).

Ungulates need continuous intake of dietary nitrogen (Holá, 2016). Dietary nitrogen is the most limiting nutrient compared to other food components, such as fat, especially during critical periods of the animal life cycle, such as pregnancy, lactating and fetal development for grazers (Grant *et al.,* 2000; Gil–Jiménez *et al.,* 2015). Dietary nitrogen is also the most common constituent of feces used to assess diet quality of forageing animals (Holechek, 1982; Kamler and Homolka, 2005; Monteith *et al.*, 2014; Rayn, 2016). Hence, in the present study, common warthogs consumed more mean proportion of dietary nitrogen during the wet season than during the dry seasons in GCHA. This could be due to in semi–arid savanna ecosystem, large proportions of available forage species become lignified and hard to digest during the dry season than the during wet season. Thus, the protein content of these forage species declines below 1.1% and fail to provide sufficient dietary protein (Mphinyane *et al.*, 2015; Rayn, 2016). The variation in dietary nitrogen is also closely related to phenology of the forage species (Jianzhang *et al.,* 1999). During the present study, common warthogs defecated more mean proportion of fecal nitrogen during the wet season than during the dry season in HADCHA. This might be due to fecal nitrogen was likely related to the consumption of forage species and season. Hence, it is the main factor which affects their availability and quality (Mphinyane *et al.,* 2015). The mean fecal nitrogen calibrated in GCHA and HADCHA was comparable during the dry season. The finding of the present study was strongly conflicted with Treydte *et al.* (2006), who

measuredlower fecal nitrogen (1.5%). On other hand, in the present study, fecal nitrogen defecated by common warthog was higher thandietary nitrogen utilized by warthogs in both study areas. This might be due to salt licking habit which supplemented the fecal nitrogen of the common warthogs.On the other hand,high fecal nitrogen calibrated indicated that the animals did not suffer from shortage of dietary nitrogen in both study areas (Treydte, 2004). However, the fecal and dietary nitrogen of the study areas were positively correlated. Several studies also reported positive linear relationship existed between fecal and dietary nitrogen in feeding activity of ungulates (Holecheck,1982; Irwin *et al.*, 1993; Kamler and Homolka, 2005; Jean *et al.*, 2014; Holá, 2016).

Dietary phosphorousis essential for bacterial degradationof dietary fibers (Metzler and Mosenthin, 2008; dos Passos, 2014). It is also important for grazing ungulates reproductive process and may even restrict animal distributions (Grant *et al.*, 2000). Dietary phosphorous was predicted from forage species of animals (Wrench *et al.*, 1997; Augustine, 2004; Codron *et al.*, 2005). In the present study, fecal phosphorous concentration of common warthog varied between 1311 mg/100g and 1489.2 mg/100g. This showed that common warthog population of both study areas suffered from shortage of dietary phosphorous. This restricts reproductive process and animal distribution over long period of feeding. Because fecal phosphorous concentration 1900 mg/100g to 2000 mg/100g indicated that dietary phosphorous minimum threshold level animal consumed(Grant *et al.*, 2000). This might be lead to low reproductive rates and population decline of these animals in Dabena Valley Forest. On the other hand, dietary phosphorous utilized by common warthogs and fecal phosphorous concentration defecated did not show significant variation between seasons and the study areas.

Ungulates require dietary crude protein (DCP) to maintain their body weight (Mgqasta, 2010). In the present study, seasonal mean proportion of DCP foraged was higher during the wet season than during the dry season in HADCHA. This could be due to the decline in quality and quantities of foods during the dry season (Mgqasta, 2010; Thorp, 2012). The result of the present study contradicted with Clauss *et al.,* (2008), who measured smaller DCP (period 1= 14.6%, period 2=15%) for captive common warthogs at Rotterdam Zoo. On the other hand, during the present study, seasonal mean proportion of fecal crude protein (FCP) content of common warthog was higher during the wet than during the dry season in GCHA. The finding of the present study was similar with Clauss *et al.* (2008), who measured FCP (period 1= 82%, period 2=79%). The mean proportion of FCP was higher than DCP common warthogs ingested in both study areas and they were negatively correlated. This might be due to common warthog additionally ingested soil licks and wood shavings (Clauss *et al.,* 2008).

Among common warthogsand other wild pigs,dietary fiber is an inevitable component of their diets (Metzler and Mosenthin, 2008), and important for intestinal health (Mahenya, 2016). They use microbes in their cecum and colon to extract energy from a fibrous diet (Zervanos, 2009). Soluble dietary fiber may promote digestive functions and absorption of nutrients (Clauss *et al.,* 2008; Zijlstra *et al.,* 2015). Insoluble fiber diets also improve gut morphology by increasing villi length and stimulating mucosal enzyme activity (Metzler and Mosenthin, 2008). Likewise, common warthogs are more efficient than other wild suids and peccaries in terms of fiber digestion (Clauss *et al.,* 2008). Neutral detergent fiber (NDF) content of feces used as a predictor for digestible energy of the diet and NDF might be used to identify the most digestible plant

species (Jean *et al.,* 2014). Hence,in the present study, NDF content of forage energy utilized by common warthog was consistent in GCHA and HADCHA. Thefinding of the present study was not far from the threshold value calibrated (60–65%) for grazers (Kamler and Homolka, 2005; Monteith *et al.,* 2014). Therefore, common warthog utilized reasonable forage energy of NDF in the study areas (Metzler and Mosenthin, 2008). However, the finding of the present study was contradicted with Clauss *et al.* (2008), who measured forage energy of NDF smaller during period 1=20.6% and NDF during period 2= 21% for captive common warthogs at Rotterdam Zoo. On the other hand, common warthog NDF content feces was comparable in HADCHA and GCHA. The finding of the present study was little higher than the value measured for NDF content of feces by Clauss *et al.,* (2008), 66% and 63% during different periods.

Acid detergent fiber (ADF) is the least digestible fiber in most herbivores (Monteith *et al.,* 2014; Holá, 2016). It has long been used to estimate energy content of forage species (Zweifel–Schielly *et al.,* 2012). Hence, ADF is used as a predictor of forage digestibility as NDF is an estimator of forage intake of animals (Monteith *et al.,* 2014). The upper threshold level of ADF content of forage is 50% for grazers (Holá, 2016). Likewise, the forage content of ADF that common warthog utilized was consistent in GCHA and HADCHA. Hence, forage contents of ADF, common warthog consumed in both study areas showed modest digestibility (Kamler and Homolka, 2005). The finding of the present study was very far from Clauss *et al.,* (2008), who calibrated the feces content of ADF 11.6% and 11.9% during period 1 and 2, respectively. Moreover, ADF content of feces the animal defecated was higher in GCHA and less in HADCHA. This finding was very close to the finding of Clauss *et al.,* (2008), who measured 62% and 59% ADF content of feces during period 1 and 2, respectively.

Peoples' view toward common warthog conservation

Ungulates are key economic and ecological actors in terrestrial ecology (Holdo *et al.,* 2010; Pringle, 2010). Super abundant species that simultaneously play as ecosystem engineers, tourist attractions, and food resources often characterize these biomes (Holdo *et al.,* 2010; Muñoz, 2013). However, anthropogenic factors cause a severe decline of these species (Mccauley *et al.,* 2006; Georgadis *et al.,* 2007; Muñoz, 2013). Human pressures, accessibility of suitable forage, and cover, restrict increasingly the distribution of common warthog species (Grubb, 1993). During the present study, comparable higher number of respondents of GCHA and HADCHA realized that the common warthog populations were declined in the study areas. Similarly, De Jong *et al.* (2016), found that most of common warthog populations declined over much of their geographic ranges. On the other hand, comparable smaller number in GCHA, and HADCHA respondents confirmed that the animals increased in their habitats. The value of the present finding was different from the finding of Abdulfatah Abdu and Demeke Datiko (2017), who reported 51.28% of respondents claimed that the number of common warthog population decreased and 40.24% of the respondents realized that the number increased in Diregudo Forest of Gololcha Woreda, southeast Ethiopia. However, the status of common warthog population of the present study was better than the finding of Magadla *et al.,* (2016), who found 25% of the respondents claimed that the number of common warthog populations increased in South Africa.

Crop raiding is a cause of conflict between farmers and wildlife throughout the world (Georgadis *et al.,* 2007; Bukie *et al.,* 2018). Farmers revenge against crop raiding leading to a major threat

and local extinction of wildlife (Georgadis *et al.,* 2007). During the present study, similar numberof GCHA and HADCHA village respondents confirmed that crop raiding was the major threat of common warthogs in the study areas. All village residents depended on crop production for their survival and concerned about crop loss by wildlife (Bukie *et al.,* 2018). Likewise, the present study agreed with Abdulfatah Abdu and Demeke Datiko (2017), who found the whole village respondents recognized that the crop raiding by common warthogs was the major threat of the animal in Diregudo Forest. However, the present study was inconsistent with the study of Hjertlöv (2015), who explained that common warthogs did not destroy any crop and people seemed to be friendly with warthogs at Kichwa tembo Safari in Kenya.

Habitat degradationand fragmentation induced by anthropogenic pressures are among the major drives imposing upon ecological services and earth's biodiversity (Georgadis *et al.,* 2007; Karanth *et al.,* 2009; Said *et al.,* 2016). Previous study by Abdulfatah Abdu and Demeke Datiko (2017) claimed that habitat destruction and fragmentation were the main causes of human and common warthog conflict and threat of the animal. Similarly, during the present study village respondents of both study areas realized that habitat degradationand fragmentation induced by anthropogenic pressures were the major threats to common warthog population in both the study areas. This could be dueto the greater demand on land for agricultural expansion and honeybee production to meet their requirement (Georgadis *et al.,* 2007).

Biological systems are also being affected by drought, which introduce changes in biophysical conditions that influence their development and maintenance (Alho and Silva, 2012). Its impact

is almost never been quantified (Duncan *et al.,* 2012). Drought creates opportunities for pathogens to expand their range and result in morbidity or mortality of wildlife (Illius and O'Connor, 2000; Alho and Silva, 2012; Duncan *et al.,* 2012). Pathogens at low infection levels because of temperature restrictions become fatal and endemic as temperature goes beyond the upper limit (Alho and Silva, 2012). Drought affected common warthog populations in Maasai Mara safari in Kenya because of prolonged dry season reported for many years in the area (Hjertlöv, 2015). Drought ranked 2nd threat for common warthog population with possibly increasing with warmer climate extreme in South Africa (Swanepoel *et al.,* 2016). Similarly, during the present study village respondents confirmed that drought was the ranked threat of common warthog population. This might be due to drought also dramatically increased rates of vegetation breakdown in arid lowland and affected the life of common warthog population (Alho and Silva, 2012; Gandiwa *et al.,* 2016).

Hunting wildlife, mainly sport hunting is a very common practice in Africa (Crosmary *et al.,* 2012; Beale *et al.,* 2013). In recent studies, there has been much debate concerning the relationship between sport hunting and conservation (Palazy *et al.,* 2011; Mysterud, 2012). Because behavioral adjustments in response to hunting risk African ungulates (Crosmary *et al.,* 2012) and trophy hunters are not usually selective (Mysterud, 2012). Similarly, during the present study, common warthog populations of both study areas were under the threat of sport hunting. Hunting was the first threat of common warthogs in the South Africa (Swanepoel *et al.,* 2016). Predation constitutes an important feature of the biotic environments of wild ungulates (Cronje *et al.,* 2002) and also remains threat to common warthog population throughout their ecological ranges (Hjertlöv, 2015; De Jong *et al.,* 2016; Swanepoel *et al.,* 2016). Hence,

common warthog population was the most frequently consumed species by predators (Cumming, 2013; Creel *et al.,* 2018; Williams *et al.,* 2018). Likewise, during the present study, village respondents realized that predation is also another threat of common warthog population in the study areas. This could be due to behavioral response to human hunting exposing ungulate species to their natural predators (Crosmary *et al.,* 2012).

African swine fever (ASF) is highly contagious and viral hemorrhagic diseaseaffecting common warthog population throughout its range (Everett *et al.,* 2011; Magadla *et al.,* 2016; Swanepoel *et al.,* 2016; Brown and Bevins, 2018). The animal is also susceptible to an acute and highly contagious viral disease known as rinderpest (Cumming, 2013; De Jong *et al.,* 2016) and protozoan blood disease; *Trypanosomiasis* (Bengis and Erasmus, 1988; Glover, 1996). Similarly, in the present study village respondents witnessed that certain diseases threatened common warthog population in both study areas.

Human attitudes towards wildlife are more than just a collection of beliefs, emotions and behaviors (Benka, 2012). But it is the interrelationships among societal norms, values and value orientations and are key drivers of attitudes and dictate human behavior towards wildlife (Benka, 2012; Beale *et al.,* 2013). Because the need and behavior of wildlife impact negatively on the goals of humans or the goals of humans negatively impact the needs of wildlife (Mulonga *et al.,* 2003; Madden, 2004). Hence, during the present study, high number of GCHA and HADCHA respondents had negative attitude towards common warthog population. Crop damage by common warthogs might have influenced their attitude against warthogs. However, some of

HADCHA and GCHA respondents had positive attitude toward warthogs. The finding of the present study was similar with those of Swanepoel (2016), who realized that majority of respondents had negative attitude and few had positive attitude toward the presence of common warthog in South Africa. Contrary to this, the finding of the present study was inconsistent with the finding of Abdulfatah Abdu and Demeke Datiko (2017), who found few of the respondents had negative attitude and morerespondents had positive attitude towards common warthog population in Diregudo Forest of Gololcha Woreda, southeast Ethiopia.

Human–common warthog conflict and other natural threats indicated that the species critically needs conservation actions (Beale *et al.,* 2013; Hjertlöv, 2015;De Jong *et al.*, 2016). Likewise, during the present study, morerespondents of GCHA than HADCHA thought that conservation action of common warthog was not important in the study areas. On the other hand,morerespondents of HADCHA than GCHA believed that conservation action of the warthogis required in the study areas. The present study was in agreement with Abdulfatah Abdu and Demeke Datiko (2017), who confirmed that of majority the respondents (69.86%) denied conservation of common warthog and some of them (30.14%) supported the conservation of warthog in Diregudo Forest of Gololcha Woreda, southeast Ethiopia. The finding of the present study was inconsistent with the study of Lindsey (2011), who realized 95.4% of respondents supported conservation of common warthog in Namibia and 72% believed the need of conservation of the animal in South Africa (Swanepoel, 2016).

8. CONCLUSION AND RECOMMENDATIONS

8.1. Conclusion

Despite high anthropogenic pressures, the current common warthog population sounder size is larger in both study areas compared to those estimated elsewhere in its range. This was positively correlated with the predation detection and alarming situations effectively to their group members. However,segregation and migration unbehaviorally will threaten the future trend of this animal as the anthropogenic pressure continued particularly in GCHA. Hence, strict follow up of this animal is undoubtedly important in the study areas. Variation in season affected sounder size. On the other hand, population abundance and cluster density of the animals were also higher than other studies conducted elsewhere in the country and in some of its range. Common warthog population sightings, encounterrate, MDP and were consistent in GCHA, and HADCHA because of homogeneous habitat features of DVF in both study areas.

Even though common warthog population preferred *Combretum–Terminalia* habitat,open grassland and riparian forests habitats in both study areas, the highest abundance was recorded in *Combretum–Terminalia*. Likewise, population abundance and cluster density of common warthog population were also highestin *Combretum–Terminalia* habitats of both study areas. This is associated with better cover and forage facilities found in *Combretum–Terminalia.*Activity patterns of common warthogs in these habitats were associated with ambient temperature and intensity of solar radiation in both study areas. However, there were

significantly different among diurnal activities in the mean duration of time engaged by common warthog based on their physiological interest and physical barrier avoidance. Similarly, there were variation between AF and AM in the mean length of time allocated for various diurnal activities. Season also affects the mean length of time engaged in different activities. Like many large herbivorous animals, common warthog population also spent majority of their diurnal time for feeding. Some activities showed inverse correlation with other behavioral activities. Thus, each behavioral activity of the animals peaked in its particular time block of the day.

Common warthog population forageon wide range of food resourcesof graminoids, herbs, shrubs, and climbers in both study areas. However, graminoids constituted the highest palatable forage species of the animal. Common warthogs were curious in the choice of high quality forage species, particularly whenthere was shortage of nutrients during the dry season. Certain staple forage species were frequently preferred, because of their compatibility with body of animals whereas nutritionally poor and undigested forage species were usually rejected. Some of these forage species were ecologically restricted to the country and failed under the influence of seasons. Common warthog population also supplemented their forage intake by licking different mineral elements from the ground. Mineral lick also benefits the animals in regulating the state body equilibrium and defending pathogens invading the animal's body. The licking demand of common warthog population was peaked during the dry season than during the wet season. Adult female common warthogs were highly attracted to lick sites than AM, because their instinct maternal responsibilities.

Diet analysis and microhistological study of common warthog population have indicated that they were not suffered from poor nutritional quality intake except dietary phosphorous concentration in both study areas. Common warthog populations are currently foraged dietary phosphorous concentration below the minimum thresholdlevel, which gradually affects the fertility and population size of the animal in the study areas. Common warthogs are highly efficient in dietary fibers (ADF and NDF) digestion. On the other hand, there were significant variations between dietary C, N, CP, and fecal contents of C, N, and CP because of salt licking behavior. Some of these dietary and fecal contents were influenced by seasons and showed variation between the two study areas. Conservation action of this animal was rejected by village respondents of both study areas. Respondents developed negative attitude towards common warthog population due to crop raiding. Habitat degradation, drought, outbreak of diseases and predators were the major threats of common warthog population in both study areas.

8.2. Recommendations

Based on the findings of the present study, the following recommendations are suggested in order to sustain the life of common warthog populations in GCHA and HADCHA.

- People around GCHA and HADCHA should avoid their cattle not to share the resources.
- Government officials and conservationists should immediately revise human resettlement program practiced in the buffer zone of GCHA. The resettlement program did not satisfy resettlers and also negativelyaffected onthe behavioral patterns of common warthog populations and other wildlife.
- People around GCHA and HADCHA who are engaged in honey bee farming and utilize different wild spices in the areas should have moral reason to use it in sustainable ways
- Terrace farming and local soil protection mechanism should be implemented in order to alleviate mineral elements running off,which particularly affects the nutrient quality of common warthogs.
- Deforestation and chasing away off wildlife form their habitats should be stopped in the study areas
- Conservation of GCHA and HADCHA should get local community acceptance. Because Didesa River, which bisected the study areas is a significant catchment area of Abay basin and the largest drainage of the upper Blue Nile River Basin
- GCHA and HADCHA should have clear demarcations and scouts should make frequent patrol of boundaries.

- The growing up of socio–economic problems of rural residents around the controlled hunting areas should be resolved in a sustainable way to break the chain of poverty, which usually abuses most of wildlife
- Farmers should not cultivate crops around the buffer zones of the study areas to mitigate crop raiding problems
- Sport hunting activity, particularly exercised in HADCHA should be evaluated by concerned bodies
- Wildlife laws should be introduced and practiced in the study areas.
- Experts should study further wildlife potential resources of the study areas in detail.

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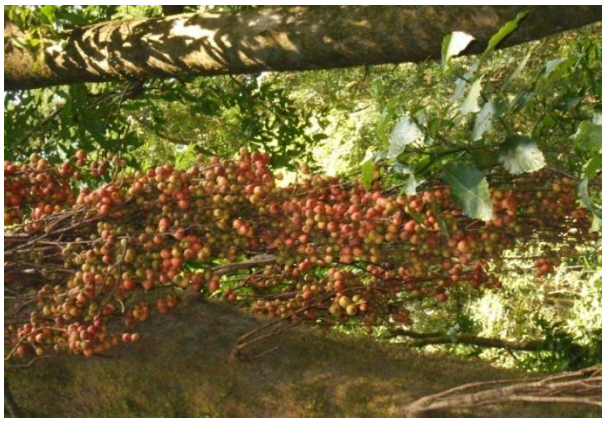
10. PLATES

Dracaena steudneri

Hyparrhenia rufa

Cynodon nlemfuensis



Ficus sur

Cyperus fischerianus

Terminalia brownii

Plate 1. Different plants consumed by common warthogs during the wet season (Photo: Alemayehu Edossa April, 2017).

Plate 2. Habitat destruction in GCHA (Photo: Alemayehu Edossa, 2017).

Plate 3. Wild honey in HADCHA (Photo by Alemayehu Edossa, April, 2018).

Plate 4. Wild fruit in GCHA (Photo by Alemayehu Edossa, April, 2018).

Plate 6. Partly undigested *Eleusine coracana* in feces of common warthog (Photo by Alemayehu Edossa, 2017).

11. APPENDICES

Appendix I. List of medium sized and large mammals of the study areas

No	Common name	Sientific name
1	Buffalo	*Syncerus caffer*
2	Common warthog	*Phacochoerus africanus*
3	bush pig	*Potamocherus larvatus*
4	giant forest hog	*Hylochoerus meinertzhageni*
5	bushbuck	*Tragelaphus scriptus*
6	Guenther's dik–dik	*MAMoqua guentheri*
7	waterbuck	*Kobus ellipsipprymu*
8	Vervet monkeys	*Chlorocebus pygerythrus*
9	olive baboon	*Papio anubis*
10	savanna baboon	*Papio cynocephalus*
11	blue monkeys	*Cercopithecus mitis*
12	colobus monkey	*Colobus guereza*
13	Aardvark	*Orycteropus afer*
14	lion	*Panthera leo*
15	leopard	*Panthera parAMus*
16	spotted hyaena	*Crocuta crocuta*
17	African civet	*Civettictis civetta*
18	cheetah	*Acinonyx jubatus*
19	honey bAMger	*Mellovora capensis*
20	common jackal	*Canis aureus*

Appendix II. Common warthog population data recorded from GPF

Site	Habitat	Length in m	Strip width in m	Area in M2	Sightings	Cluster size	Mean	Total	P1	P2	P3	P4
Miesso–1	Comb– Term	1950	12	23400	2	2, 6	4	8	0.3	0.4		
' " 2	Comb– Term	1970	16	31520	2	3, 8	5.5	11	0.6	0.7		
' " 3	Comb– Term	1960	17	33320	3	4, 6, 4	4.6	14	0.6	0.6	0.9	
' " 4	Riparian forest	610	8	4880	2	1, 4	2.5	5	0.7	0.9		
' " 5	Riparian forest	617	9	5553	0	0	0	0	0	0		
' " 6	Riparian forest	623	10	6230	2	2, 5	3.5	7	0.9	0.7		
' " 7	Comb– Term	1874	14	26236	2	5, 3	4	8	0	0.7		
' " 8	Comb– Term	1565	12	18780	1	0, 1	0.5	1	0	0.1		
Seba –1	Riparian forest	620	10	6200	2	2, 5	3.5	7	0.3	0.6		
' " 2	Comb– Term	1970	23	45310	3	7, 5, 6	6	18	0.8	0.4	0.3	
' " 3	Open grass land	800	48	38400	3	3, 3, 10	5.3	16	0.4	1	0.1	
' " 4	Comb– Term	1980	21	41580	2	5, 8	6.5	13	0.5	0.5		
' " 5	Open grass land	915	34	31110	2	4, 3	3.5	7	0.2	0.4		
' " 6	Riparian forest	765	12	9180	2	2, 2	2	4	1	0		
' " 7	Comb– Term	1490	14	20860	2	1, 6	3.5	7	0.5	0.6		
' " 8	Comb– Term	1670	18	30060	2	3, 1	2	4	0.6	0.2		
Lemana–1	Comb– Term	1950	16	31200	3	3, 2, 3	2.6	8	0.3	0.5	0.1	
' " 2	Open grass land	810	36	29160	2	2, 3	2.5	5	0.1	0		
' " 3	Riparian forest	600	8	4800	1	0, 4	2	4	0	0.2		
' " 4	Comb– Term	1950	17	33150	2	4, 5	4.5	9	0.3	0.6		
' " 5	Riparian forest	675	15	10125	2	1, 2	2	3	0.5	0		
' " 6	Riparian forest	795	9	7155	0	0	0	0	0	0		
' " 7	Comb– Term	1348	12	16176	2	2, 1	1.5	3	0.9	0		
' " 8	Comb– Term	1475	17	25075	3	3, 2, 4	3	9	0.3	0.3	0.1	
Menjiko–1	Open grass land	820	21	17220	3	3, 4, 5	4	12	0.5	0	1	
' " 2	Riparian forest	620	13	8060	2	2, 4	3	6	0.7	0		
' " 3	Comb– Term	1980	14	27720	3	3, 4, 11	6	18	0.5	0.1	0.2	
' " 4	Comb– Term	2000	15	30000	4	2 ,4, 6, 8	5	20	0.1	0.4	0.5	0.8
' " 5	Riparian forest	768	9	6912	2	2, 5	3.5	7	0.2	0.2		
' " 6	Comb– Term	1276	13	16588	2	1, 1	1	2	0.8	0.5		
' " 7	Open grass land	893	32	28576	3	3, 5, 2	3.3	10	0.4	0.5	0.5	
' " 8	Comb– Term	1407	16	22512	0	0	0	0				

Appendix III. Common warthog population data recorded from HADPF

Site	Habitat	Length in m	Strip width in m	Area in M2	Sightings	Cluster size	Mean	Total	P1	P2	P3	P4
Robe –1	Comb– Term	1950	12	23400	2	5, 13	9	18	0.6	0.3		
' " 2	Comb– Term	1960	15	29400	3	9, 5, 8	7.3	23	0.7	0.21	0.3	
' " 3	Comb– Term	1950	16	31200	2	8, 9	8.5	17	0.6	0.7		
' " 4	Riparian forest	600	10	6000	2	1,5	3	6	0.75	0.32		
' " 5	Riparian forest	708	14	9912	3	7, 6, 9	7.3	22	0.4	0.2	0.9	
' " 6	Comb– Term	1248	16	19968	2	5, 11	8	16	0.4	0.6		
' " 7	Comb– Term	1507	13	19591	2	4, 7	5.5	11	0.4	0.2		
' " 8	Comb– Term	1284	12	15408	2	2, 3	2.5	5	0.5	0.2		
Desa–1	Comb– Term	630	9	5670	2	2, 7	4.5	9	0.5	0.2		
' " 2	Comb– Term	1990	17	33830	2	11, 14	12.5	25	0.6	0.8		
' " 3	Comb– Term	1980	23	45540	3	6, 7, 18	16.5	31	0.01	0.8	0.01	
' " 4	Open grass land	810	22	17820	2	6, 11	8.5	17	0.1	0.2		
' " 5	Open grass land	765	25	19125	2	4, 9	6.5	13	0.5	0.8		
' " 6	Comb– Term	1387	14	19418	2	9, 12	10.5	21	0.5	0.7		
' " 7	Comb– Term	1678	12	20136	3	8, 7, 19	17	34	0.1	0.6	0.7	
' " 8	Riparian forest	930	10	9300	1	4, 7	5.5	7	0.16	0.65		
Gimbich–1	Riparian forest	650	9	5850	2	3, 9	6	12	0.5	0.6		
' " 2	Comb– Term	2000	25	50000	4	7, 6, 8, 12	8.25	33	0.2	0.8	0.6	0.3
' " 3	Open grass land	840	50	42000	3	8, 8, 20	12	36	0.2	0.5	0.2	
' " 4	Comb– Term	2000	24	48000	3	8, 4, 16	9.3	28	0.4	0.6	0.8	
' " 5	Comb– Term	1763	17	29971	2	5, 7	6	12	0.4	0.7		
' " 6	Open grass land	763	31	23653	3	11, 9, 10	10	30	0.7	0.2	0.8	
' " 7	Riparian forest	923	12	11076	3	8, 10, 11	9.6	29	0.2	0.9	0.1	
' " 8	Comb– Term	1478	8	11824	2	10, 4	7	14	0.4	0.7		
Dodeta–1	Comb– Term	1970	25	49250	2	8, 11	9.5	17	0.7	0.2		
' " 2	Riparian forest	630	12	7560	2	4, 9	6.5	13	0.33	0.9		
' " 3	Open grass land	790	37	29230	2	10, 16	13	26	0.2	0.4		
' " 4	Comb– Term	2000	25	50000	4	5, 11, 10, 12	9.5	38	0.3	0.5	0.3	0.5
' " 5	Comb– Term	1676	16	26816	2	5, 13	9	18	0.4	0.8		
' " 6	Open grass land	813	28	22764	2	7, 7	7	14	0.2	0		
' " 7	Riparian forest	687	9	6183	2	8, 15	11.5	23	0	0.4		
' " 8	Comb– Term	1784	14	24976	3	5, 7, 16	9.3	28	0.4	0.3	0.8	

Appendix VI. Common warthog population categories and distance data collecting sheet

Season Date: Site Observer(s):

Transect: Bearing: Length:
Start coordinates: Time started transect:
End coordinates: Time finished transect:

No	**Cluster size (number of animals)**						**Distance (m)**	**Angle (0–90°)**	**Habitat type**
	Am	**Af**	**SAm**	**SAf**	**Uns**	**Juv**			

AM= AdultMale, AF= Adult Female, SAM= Sub–Adult Male, SAF = Sub–AdultFemale

UJS= Unidentified Juvenile Sex

Appendix V.Diet composition analysis sheet of common warthog

Field of view	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
Total																									

Field of view	Number of identified plant particles in the field of view												Number of unidentified plant particles									Grass	herbs
	30	31	32	33	34	35	36	37	38	39	40	41											
1																							
2																							
3																							
4																							
5																							
6																							
7																							
8																							
9																							
10																							
Total																							

1= < 5%, 2= 6–10%, 3= 11–15%, 4= 16–20% , 5= 21–25%, 6= 26–30%, 7= 31– 35%. 8= 36–40% , 9= 41–45%, 10= 46=50% ,11= 51–55%, 12= 56–60%, 13= 61–65%, 14= 66–70% , 15= 71–75%, 16= 76–80%, 17= 81– 85%. 18= 86–90%, 19= 91–95%, 20= 96=100%

Appendix VI. Questionnaire for village respondents about attitudes and the need of conservation of common warthog population

AMdis Ababa University, School of GrAMuate Studies, Department of Zoological Sciences, Ecological and Systematic Zoology Stream questionnaires used to collect information and views about common warthog conservation status from people living in and around the study areas (GCHA and HADCHA)

I kindly thank you for the time and effort you put with me to respond to the questionnaires

I. Biographic information of respondents

A. Gender: Male ☐ Female ☐

B. Age: 18–30☐ 31–40☐ 41–5☐51

C. Educational status: uneducated ☐Non–formalPrima☐Secondary ☐

10 complete ☐ 12 complete ☐ 12+3☐ BA/ BCS ☐

D. Occupation: Farming☐Farming and merchant Student ☐ Civil servant ☐

E. Village you live

E. How long have you lived in the area?

15–20years ☐ 21–25years☐ 26–30years ☐ >31years ☐

II. Common warthog information

1. Is the number common warthog population in this study area?

A. Increasing ———— B. decreasing ———— C. no change ——— D. no idea ————

2. Rank of the major threats of common warthog of the study areas (GCHA or HADCHA)

A. Predators B. Domestic hunting C. Sport hunting

D. Shortage of foods E. Drought F. Shortage of water

G. Disease (rinderpest) H. Habitat degradation, I. Response to crop raiding

J. Others if any

3. What is your attitude towards the presence of common warthog in the study area?

A. Positive B. negative C. neutral

4. What is the level of crop damage by the common warthog in the area you live?

A. Very much B. Much C. insignificant D. no damage

5. How do you protect your crop damage by common warthog in the study area? You can answer more than one option?

A. Shooting B. guarding crops C. fencing D. chasing and shouting E. trapping F using dogs

6. Is it important to take conservation actions of common warthog in the study area?

A. Yes B. No C. No idea

7. If "Yes" the above question, what type of conservation measures should be taken? List down

_____

8. What human activities could affect the normal behavior of common warthog in the controlled hunting area? You can answer more than one option

A. Apiculture B. crop farming C. deforestation D. cattle grazing E. all

9. If common warthogs and other wildlife deliberately kill the local people, do the residents make aware of the Woreda officers? _____and

Do the officers detect and take corrective measure? _____

10. Do you think that, sport hunting action in the study areas could support the conservation plan of wildlife including common warthogs and others?

_____

Appendix VII. List of plant species recoded as diets of common warthog in GCHA

Family	Species	Season	Family	Species	Season
Graminoids=25				**Herbs= 11**	
Cyperaceae	*Cyperus fischerianus*	W, D	Arecaceae	*Borassusa ethiopum*	W, D
Cyperaceae	*Cyperus distans*	W, D	Boraginaceae	*Cordia africana*	D
Cyperaceae	*Cyperus papyrus*	W, D	Combretaceae	*Terminalia brownii*	W
Cyperaceae	*Cyperus longus*	W, D	Commelinaceae	*Commelina benghalensis*	W
Poaceae	*Digitaria ciliaris*	W, D	Dracaenaceae	*Dracaena steudneri*	W
Poaceae	*Digitaria abyssinica*	W, D	Fabaceae	*EntAMa abyssinica*	W, D
Poaceae	*Eragrostis tef*	D	Fabaceae	*Sesbania sesban*	W
Poaceae	*Zea mays*	D	Moraceae	*Ficus sycomorus*	D
Poaceae	*Sorghum bicolor*	D	Moraceae	*Ficus sur* (*F. capensis*)	D
Poaceae	*Eleusine coracana*	D	Moraceae	*Ficus vasta*	D
Poaceae	*Triticum aestivum*	D	Salicaceae	*Salix mucronata*	W, D
Poaceae	*Cynodon dactylon*	W, D			
Poaceae	*Cynodon nlemfuensis*	W, D		**Shrubs=3**	
Poaceae	*Hyparrhenia rufa*	W, D	Apiaceae	*Diplolophium africanum*	W
Poaceae	*Eragrostis spp,*	W, D	Brassicaceae	*Sisymbrium maximum*	W
Poaceae	*Hyparrhenia hirta*	W, D	Euphorbiaceae	*Tragia pungens*	W, D
Poaceae	*Hyparrhenia varibilis*	W, D			
Poaceae	*Panicum maximum*	W, D			
Poaceae	*Pennisctum nubicwn*	W		**Climbers=2**	
Poaceae	*Pennisetum clandestinum*	W, D	AsclepiAMaceae	*Pergularia daemia*	W, D
Poaceae	*Pennisetum purpureum*	W	Menispermaceae	*Stephania abyssinica*	W
Poaceae	*Melinis repen*	W			
Poaceae	*Setaria poiretiana*	W			
Poaceae	*Sporobolus festivus*	W			
Poaceae	*Andropogon abyssinicus*	W, D			

Appendix VIII. List of plant species recoded as diets of common warthog in HADCHA

Family	Species	Season	Family	Species	Season
Graminoids=27				**Herbs= 12**	
Cyperaceae	*Cyperus fischerianus*	W, D	Arecaceae	*Borassusa ethiopum*	W, D
Cyperaceae	*Cyperus distans*	W, D	Boraginaceae	*Cordia africana*	D
Cyperaceae	*Cyperus papyrus*	W, D	Combretaceae	*Terminalia brownii*	W
Cyperaceae	*Cyperus longus*	W, D	Commelinaceae	*Commelina benghalensis*	W
Poaceae	*Digitaria ciliaris*	W, D	Dracaenaceae	*Dracaena steudneri*	W
Poaceae	*Digitaria abyssinica*	W, D	Fabaceae	*EntAMa abyssinica*	W, D
Poaceae	*Eragrostis tef*	D	Fabaceae	*Sesbania sesban*	W
Poaceae	*Zea mays*	D	Moraceae	*Ficus sycomorus*	D
Poaceae	*Sorghum bicolor*	D	Moraceae	*Ficus sur* (*F. capensis*)	D
Poaceae	*Eleusine coracana*	D	Moraceae	*Ficus vasta*	D
Poaceae	*Triticum aestivum*	D	Myrtaceae	*Syzygium guineense**	D
Poaceae	*Cynodon dactylon*	W, D	Salicaceae	*Salix mucronata*	W, D
Poaceae	*Cynodon nlemfuensis*	W, D			
Poaceae	*Hyparrhenia rufa*	W, D		**Shrubs = 4**	
Poaceae	*Eragrostis spp,*	W, D	Apiaceae	*Diplolophium africanum*	W
Poaceae	*Hyparrhenia hirta*	W, D	Brassicaceae	*Sisymbrium maximum*	W
Poaceae	*Hyparrhenia cymbaria* *	W	Euphorbiaceae	*Tragia pungens*	W, D
Poaceae	*Hyparrhenia varibilis*	W, D	Malvaceae	*Hibiscus macranthus* *	W
Poaceae	*Panicum maximum*	W, D			
Poaceae	*Pennisctum nubicwn*	W		**Climbers= 2**	
Poaceae	*Pennisetum clandestinum*	W, D	AsclepiAMaceae	*Pergularia daemia*	W, D
Poaceae	*Pennisetum purpureum*	W	Menispermaceae	*Stephania abyssinica*	W
Poaceae	*Melinis repen*	W			
Poaceae	*Setaria poiretiana*	W			
Poaceae	*Snowdenia polystachya* *	W			
Poaceae	*Sporobolus festivus*	W			
Poaceae	*Andropogon abyssinicus*	W, D			