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Habitat Association and Distribution of Common Warthog (*Phacochoerus africanus*) in Gassi and Haro Abo Dikko controlled Hunting Areas, Western Ethiopia

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Abstract

The study was conducted to identify habitat types common warthog population used and to assess their distribution in Dabena Valley Forest, in Gassi Controlled Area (GCHA) and Haro Aba Diko Controlled Hunting Area (HADCHA) of Western Ethiopia from May 2018 to June 2019. Data of common warthog population were collected through direct observations from the established transect lines from each habitat type. 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 ($\chi2 = 2.21$, df = 1, $P = 0.067$). Riparian forest comprised more population estimates of common warthog in HADCHA (124 (CV= 52%) with a 95% CI of (133–115) than in GCHA (28 (CV= 83%) with a 95% CI of (26–30) during the wet season. 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. Common warthog encounter rate recorded in open grassland in GCHA and HADCHA revealed significant variation ($\chi2 = 7.78$, df = 1, $P = 0.053$) during the wet season and insignificant difference ($\chi2 = 2.61$, df = 1, $P = 0.071$) during the dry season. Hence, the distribution of common warthog population in both study areas were associated with three vegetation zones along a transect line running from *Combretum–Terminalia* woodland into a grazing land in different degree.

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Keywords

Combretum–Terminalia, common warthog, density, encounter rate, riparian forest.

Introduction

The success of animals in a particular habitat type is impacted by annual variation in availability of water and seasonal cycles (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 (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 well distributed throughout *Combretum–Terminalia* woodland or broad–leaved deciduous woodland ecosystem (Kingdon, 1997; White, 2010; De Jong *et al.*, 2016). High common warthog densities in *Combretum–Terminalia* woodland or broad–leaved deciduous woodland ecosystem 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 and sufficient foraged fleshy plant species.

Common warthogs and many other ungulates forage in open grassland habitat (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 (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 (Kahana *et al.*, 2013). Common warthogs seeking this habitat for rich nutrient occur in *Brachiara* spp, *Cyodon* spp, *Panicum* spp and others (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 and other ungulates against predators (Kahana *et al.*, 2013).

Materials and Methods

Description of the study areas

Ethiopia is one of the eastern African countries rich in flora and fauna diversities. Common warthogs are widely distributed throughout Gassi controlled hunting area (GCHA) and Haro Aba Diko controlled hunting area (HADCHA) of western part of the country. The vegetation type of the study areas was identified as *Combretum-Terminalia*, open grassland and riparian forest. The study areas encompass different medium and large sized mammalian species (Edossa *et al.*, 2021).

Gassi Controlled Hunting Area (GCHA)

Gassi Controlled Hunting Area (GCHA) is located in the Oromia Regional State, Buno Bedelle Administrative Zone to the western part of the country. Most of the study sites lie in Meko and Dabohanna districts, along the Banks of the Dabena River. It is located approximately 600 km west of Addis Ababa. Gassi Controlled Hunting Area is situated in the southwestern part of Dabena Valley Forest (DVF), between 8°15″ and 8°52′ 30″ N latitude and 35°55′ 30″ and 36°7′ 15″ E longitude. The elevation ranges from 1538 to 1689 masl (Fig. 1). Gassi and Miesso rivers drain in Dabena River. Dabena Valley Forest (DVF) 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 (Merid, 2002; Awulachew *et al.*, 2007). Didessa and Dabus rivers drain the southwestern part of the basin, and contribute one third of the total flow of the Grand Ethiopian Renaissance Dam (Betrie *et al.*, 2011), which is the main sediment source of the Nile River (Ali, 2021). Gassi Controlled Hunting Area was demarcated as a controlled hunting area in 2007 with an estimated total area of 24,000 ha that includes *Combretum-Terminalia* woodland and, riparian forest (Edossa *et al.*, 2021).

This study area 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 was 1536.6 mm, with the highest mean monthly rainfall recorded in August (370.6 mm) and the lowest in December (13.3 mm). The mean monthly maximum temperature recorded was 32.3 °C in May and the mean minimum was 11.5 °C in December (Edossa *et al.*, 2021).

Haro Aba Diko Controlled Hunting Area (HADCHA)

Haro Aba Diko Controlled Hunting Area is located in the Oromia Regional State, Buno Bedelle Administrative Zone of Ethiopia to the western part of the country. It is approximately 550 km west of Addis Ababa on the southern side of Addis Ababa Nekemte-Gimbi road along the western lowland of the country. Haro Aba Diko Controlled Hunting Area is situated along the northeastern part of Dabena Valley Forest (DVF) between 8° 35′ 20″ and 8°45′ 55″ N latitude and 36° 15′ 45″ and 36°20′ 10″ E longitude. The elevation ranges from 1646 to 1720 masl (Fig. 2**).** HADCHA was demarcated in 2007 with an estimated total area of 53,841 ha that includes savanna woodland, and riparian forest. It is one of the controlled hunting areas in western Ethiopia that could be used as the future carbon sequestration center of the country (Edossa *et al.,* 2021).

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 was 1434.1 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 °C recorded in May and the mean minimum was 12.3 °C recorded in January (Edossa *et al.*, 2021).

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* wood land). Hence, habitat types throughout the study areas were classified qualitatively following the survey carried out during the first weeks of the study period.

Combretum–Terminalia habitat: This habitat type mainly comprises small to moderate–sized trees with fairly large deciduous leaves (Appendix Fig A1). These include: *Ficus,* spp, *Borassusa ethiopum, Salix mucronata, Anogeissus leiocarpa, Boswellia papyrifera* (Yetan Zaf), *Enatada africana, Stereospermum kunthianum, Terminalia brownii*, (Weyba), *Combretum* and *Lannea* (USAID, 2008). Some *Combretum* and *Terminalia* species are widely used in traditional medicine against malaria, bleeding, diarrhea, diabetes digestive disorders and inflammation (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.

Riparian forest habitat: This habitat consists of the prominent solid–stemmed lowland bamboo, *Oxytenanthera abyssinica* (Shimel) and different species of hydrophilic big trees (Appendix Fig. A2) with a combination herbs like *Justecia* spp., *Barleria spinisepala., Eulophia* spp., *Chlorophytum tetraphyllum, Hossolunda opposita* and *Ledeburia* spp. (IBC, 2009) which are foraged by common warthogs (Fig. 3). It also possesses *Sesbania sesban, Commelina benghalensis, Dracaena steudneri* and *Stephania abyssinica.* In riparian forest habitat 14 transect lines were laid to study the distribution of warthogs in both study areas.

Open grassland habitat: This comprises fire sensitive and drought tolerant graminoid species (Appendix Fig. A3). These include: *Hyparrhenia* spp., *Cynodon*, spp., and *Cyperus* spp. Which were the most abundantly occurred graminoid species in the study areas (Fig 4). Many of these grass species usually dry and local residents fire the area during March and April of dry season 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.

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 10 to 200 m 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 and population category were recorded.

Data on population abundance**,** density, sightings, encounters rate and detection probability of common warthog were collected from eight randomly selected study sites: Robe, Desa, Gimbicho, and Dodeta, in HADCHA and Miesso, Seba, Lemana, and Menjiko, sites in GCHA. Each of which study site has an area of 8 km^2. These sites were randomly selected and surveyed during the wet and dry seasons of 2016 to 2018. A total of 64 transect lines, eight from each study sites randomly assigned and covered on foot (Azhar *et al.*, 2008; Forsyth and Lange, 2012). The transect lengths were also standardize (10 km each), to carry out comparison among study sites and between study areas. Distance walked was 40 km for each study area. 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* wood land). Hence, habitat types throughout the study areas were classified qualitatively following the survey carried out during the first weeks of the study period.

Transect studies were conducted during the wet and dry seasons of the study period. Transect lines were located separately ranging from 150 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 25 m for maximum visibility in all common warthog habitats (Horcajada–Sanchez and Barja, 2015) and (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 wet season, DVF possessed partly impenetrable vegetation and its landscape was characterized by topographic ruggedness.

The centre of length and the edge of the line transects were predetermined and marked using rope and coloured 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). All common warthog individuals 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).

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 centre 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 cluster was used 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:

$$\hat{E}\,[s] = \frac{\sum_{i=1}^{n} s_i / \hat{p}_a(x_i)}{\sum_{i=1}^{n} 1/\,\hat{p}_a(x_i)}$$

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

$$\hat{N} = \frac{A}{2LW}\hat{N}_c = \frac{A}{2L}\sum_{i=}^{n} s_i . \hat{f}(0|x_i)$$

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* × *A*. Hence, cluster density of common warthog was calculated 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 *f*ˆ(0) were reduced by stratification and estimating the detection function separately by strata, respectively (Griffiths, 1978; Strindberg, 2012). During estimation of expected group size ($\hat{E}_s$) of common warthog, cluster size also checked using binocular.

Data analyses

Common warthog population's data were analyzed in Program Distance version 6.0 (Thomas *et al.,* 2009). Warthog population abundance and density data were pooled across all 8 study sites. Confidence interval and coefficient of variations were used to measure precision and variability of common warthog population abundance, density, sightings, encounter rate and detection probability. Common warthog population per transect was analyzed using t-test. Chi–square ''goodness of fit" was used to analyze the variations existed between wet and dry seasons (Kahan *et al.*, 2013).

Results and Discussion

The mean number of common warthog population that occurred 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 < 0.054) 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 < 0.48) 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 significant difference ($F_{1\,6}$ = 0.06, P > 0.059) in the mean number of common warthog population observed in open grassland habitats between the wet and dry seasons (Table 1).

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 was a significant variation ($\chi2$ = 8.17, df = 2, P = 0.39) 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 = 0.045) in the number of common warthog population (Table 1).

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 < 0.051) 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 in riparian forest was more during the dry season (17.75 ± 7.4) than during the wet season (11.25±7.27). There was a significant difference ($F_{1\,6}$ = 21.24, P < 0.058) 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 > 0.073) in the mean number of common warthog population recorded in open grassland habitats between the wet and dry seasons (Table 2).

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 a significant variations ($\chi2$ = 30.44, df = 2, P = 0.063) 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 ($\chi2$ = 41.68, df = 2, P = 0.055) in the percentage of common warthog populations (Table 2).

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 ($\chi2$ = 2.21, df = 1, P = 0.072). 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. There was no significant variation ($\chi2$ = 1.17, df = 1, P = 0.08) 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 ($\chi2$ = 8.04,df = 1, P = 0.039) 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. There was no significant variation ($\chi2$ = 3.47, df = 1, P = 0.067). Open grassland habitats in GCHA had 18 (2.0%) and

HADCHA had 54(6.0%) warthogs. There was significantly different ($\chi2 = 13.58$, df = 1, P = 0.053) 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 ($\chi2 = 12.47$, df = 1, P = 0.049) in the percentage of common warthog populations found in open grassland habitats during the dry season (Table 3).

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 ($\chi2 = 30.97$, df = 1, P = 0.044) 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) than in GCHA (28 (CV= 83%) with a 95% CI of (26–30) during the wet season. The study areas showed significant variations ($\chi2 = 11.83$, df = 1, P = 0.038) in common warthog population 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 ($\chi2 = 33.94$, df = 1, P = 0.047) in common warthog population estimate (Table 4).

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 ($\chi2 = 58$, 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 a significant variations in common warthog population estimate between the two study areas ($\chi2 = 19.58$, df = 1, P = 0.054). 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 ($\chi2 = 14.64$, df = 1, P = 0.051) in common warthog population estimate between the study areas (Table 4).

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 ($\chi2 = 9.84$, df = 2, P = 0.035) population abundance estimate of common warthogs during the wet season in GCHA (Table 5). 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 ($\chi2 = 4.2$, df = 2, P = 0.059). The number of common warthog population in *Combretum–Terminalia* ($\chi2 = 0.187$, df = 1, P = 0.078) and in riparian forest ($\chi2 = 1.12$, 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 ($\chi2 = 18.35$, df = 1, P = 0.052) in the common warthog population abundance (Table 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. There was significant variation ($\chi2 = 6.18$, df = 2, P = 0.041) 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 ($\chi2 = 1.09$ df = 2, P = 0.059) during the dry season. The density of common warthog population in *Combretum–Terminalia* ($\chi2 = 0.46$, df = 1, P = 0.073), in riparian forest ($\chi2 = 0.78$, df = 1, P = 0.063) and in open grassland habitat ($\chi2 = 0.52$, df = 1, P = 0.08) were not affected by seasons in GCHA (Table 6).

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 ($\chi2 = 11.35$, df = 2, P = 0.042) in population abundance estimate of common warthog (Table 6). 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 ($\chi2$ = 77.57, df = 2, P = 0.044).

Along these, the population abundance of common warthog in *Combretum–Terminalia* ($\chi2$ = 9.35, df = 1, P = 0.035) and in riparian forest ($\chi2$ = 8.92, df = 1, P = 0.04) and in open grassland ($\chi2$ = 15.28, df = 1, P = 0.029) habitats were affected by seasons. The dry season hosted more population abundance estimation than the wet season in the entire habitats (Table 6).

Combretum–Terminalia cluster density was higher in HADCHA (4.16 /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 ($\chi2$ = 6.34, df = 1, P = 0.027). 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 ($\chi2$ = 2.08, df = 1, P = 0.084). 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 ($\chi2$ = 5.68, df = 1, P = 0.05) during the wet season (Table 7).

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 ($\chi2$ = 3, df = 1, P = 0.057). 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 ($\chi2$ = 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 ($\chi2$ = 7.33, df = 1, P = 0.034) during the dry season (Table 7).

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 ($\chi2$ = 3.52, df = 1, P = 0.056). 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 ($\chi2$ = 0.84, df = 1, P = 0.06). The number of common warthog population sightings recorded in riparian forest of GCHA and HADCHA were not significantly different ($\chi2$ = 1.12, df = 1, P = 0.071) during the wet season and ($\chi2$ = 0.25, df = 1, P = 0.067) during the dry season. On the other hand, common warthog sightings recorded in open grassland of GCHA and HADCHA revealed insignificant variation ($\chi2$ = 2.61, df = 1, P = 0.075) during the wet season and ($\chi2$ = 0.79, df = 1, P = 0.069) during the dry season (Table 8).

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 ($\chi2$ = 2.14, df = 1, P = 0.055) 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 ($\chi2$ = 0.02, df = 1, P = 0.081). Similarly, common warthog encounter rate recorded in riparian forest of GCHA and HADCHA were not significantly different ($\chi2$ = 2.2, df = 1, P = 0.073) during the wet season and ($\chi2$ = 3.25, df = 1, P = 0.077) during the dry season. On the other hand, common warthog encounter rate recorded in open grassland in GCHA and HADCHA revealed significant variation ($\chi2$ = 7.78, df = 1, P = 0.029) during the wet season and insignificant difference ($\chi2$ = 2.61, df = 1, P = 0.069) during the dry season (Table 9).

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 ($\chi2$ = 0.37, df = 1, P = 0.057). 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 ($\chi2$ = 0.372, df = 1, P = 0.087).

Table.1 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

Table.2 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

Table.3 Percentage comparison of common warthog population in different habitats of GCHA and HADCHA during the wet and dry seasons

	GCHA		HADCHA	
Habitat				
Type	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%)

Table.4 Comparison of common warthog population abundance estimate by habitat types between GCHA and HADCHA during wet and dry seasons

	GCHA		HADCHA	
Habitat				
Type	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

Table.5 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
	w	239	256–222	2.18	2.34–2.01	80.7
Comb. Term						
	d	247	264.6–229	2.24	2.4–2.08	70
	w	28	30–26	1.25	1.34–1.16	83
Riparian						
	d	110	118–102	1.7	1.82–1.57	67.8
	w	82	88–76	1.46	1.56–1.36	58.6
Open grassland						
	d	124	133–115	2.01	2.15–1.82	72.5

Table.6 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 in km^{-2}	95% CI for CD	% CV
	w	440	471–408.6	4.61	4.94–4.28	64
Comb. Term						
	d	746	799–692.7	5.34	5.72–4.96	63
	w	124	133–115	2.18	2.34–2.02	52
Riparian						
	d	199	213–185	3.41	3.65–3.17	49
	w	271	290–251.7	3.33	3.57–3.09	37
Open grassland						
	d	314	336–291.6	4.26	4.56–3.96	68

Table.7 Comparison of common warthog density by habitat types between GCHA and HADCHA during the wet and dry seasons

	GCHA		HADCHA	
Habitat				
Type	Wet	Dry	Wet	Dry
Comb-Term	2.18/km^2	2.24/km^2	4.16/km^2	5.34/ km^2
Riparian	1.25/km^2	1.7/ km^2	2.18/km^2	3.41/ km^2
Open grass	1.46/km^2	2.01/km^2	3.33/km^2	4.26/ km^2
Total	5.44/km^2	5.95/km^2	9.67/km^2	13.01/km^2

Table.8 Common warthog sightings in GCHA and HADCHA

	GCHA		HADCHA	
Habitat				
Type	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

Table.9 Common warthog encounter rate in GCHA and HADCHA

	GCHA		HADCHA	
Habitat				
Type	Wet	Dry	Wet	Dry
Comb-Term	1.34	1.65	1.97	1.75
Riparian	1.46	2.8	3.46	2,32
Open grass	1.99	2.53	5.1	4.1
Total	4.79	6.98	10.53	5.85

Table.10 Common warthog MDP in GCHA and HADCHA

	GCHA		HADCHA	
Habitat				
Type	Wet	Dry	Wet	Dry
Comb-Term	0.371	0.448	0.433	0.53
Riparian	0.213	0.355	0.33	0.36
Open grass	0.189	0.331	0.42	0.49
Total	0.773	1.134	1.183	1.38

Fig.1 Location map of Gassi controlled hunting area.

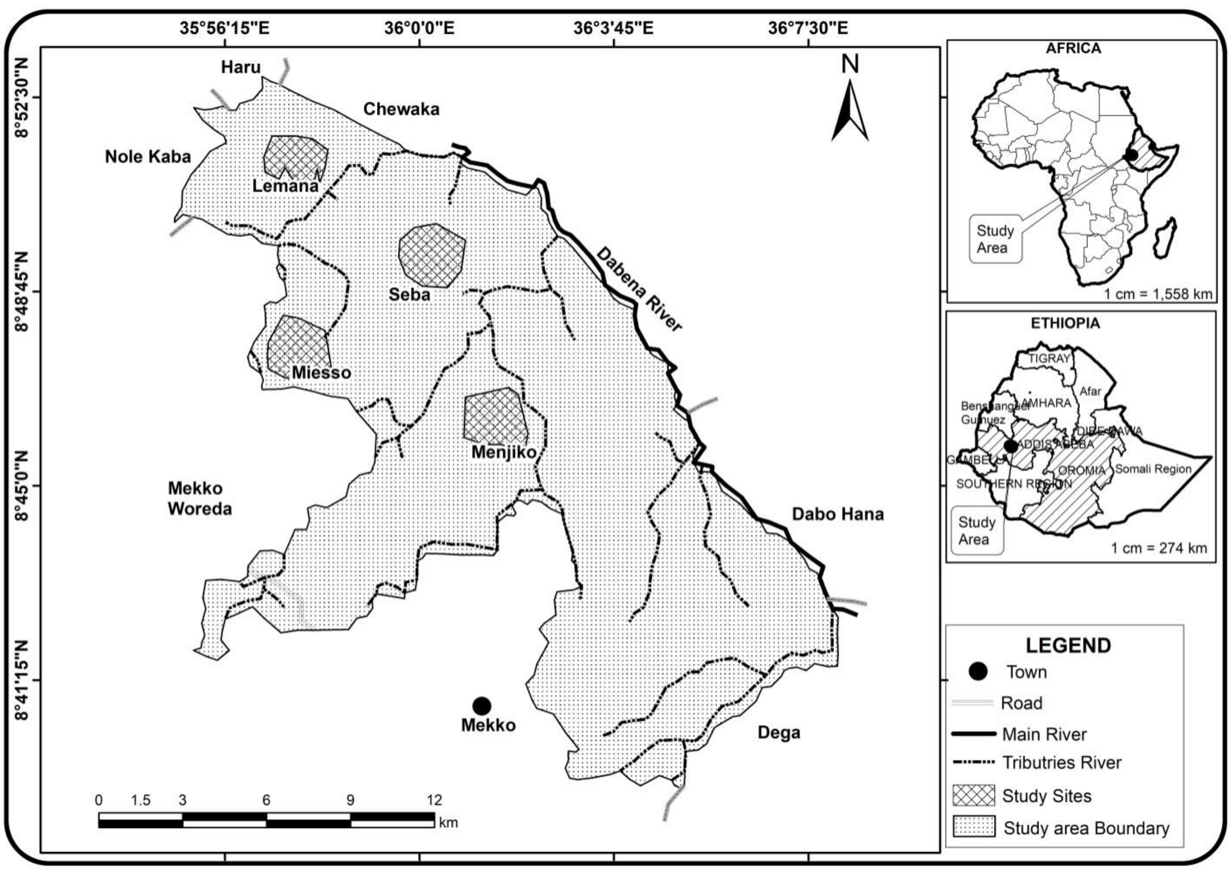

Fig.2 Location map of Haro Aba Diko controlled hunting area.

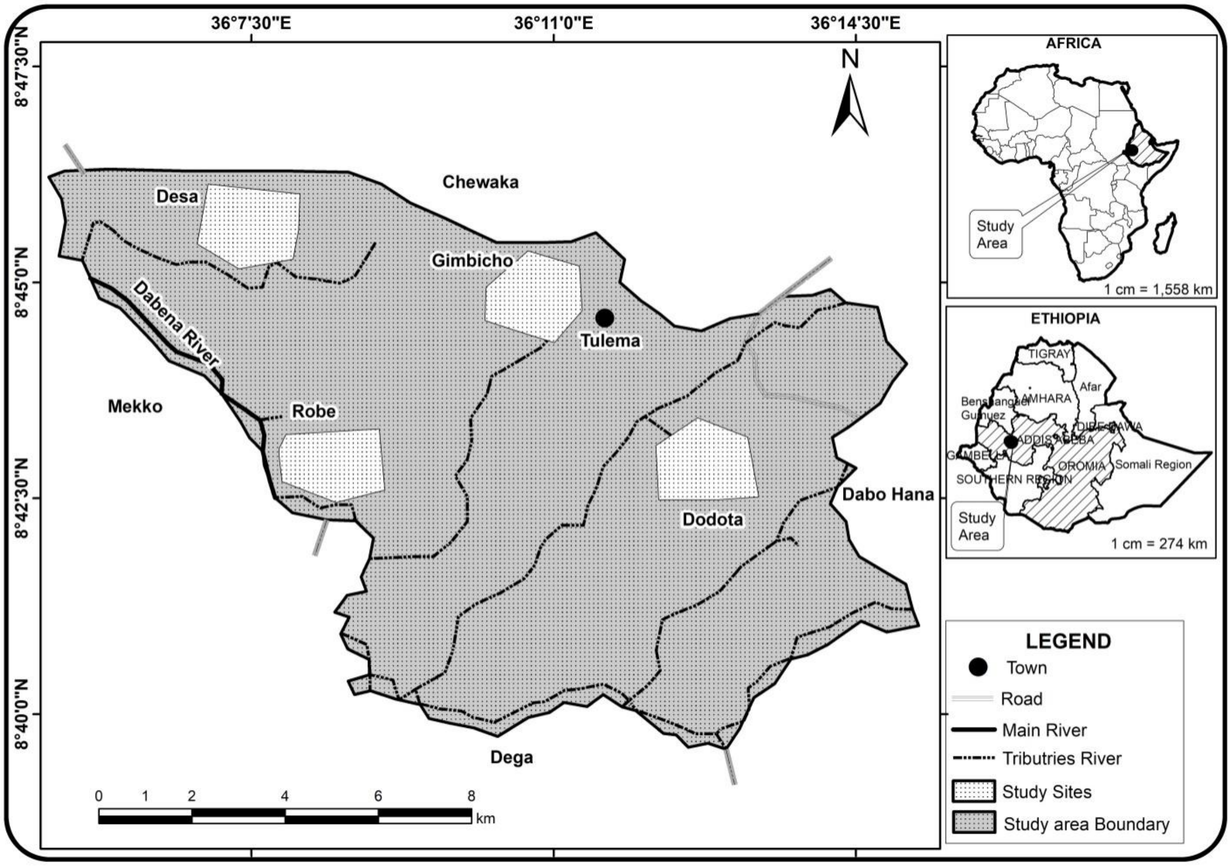

Fig.3 Common warthogs foraging in a riparian habitat (Photo by Edossa A., 2018).

Fig.4 Common warthogs grazing in the open grassland habitat (Photo: Edossa A. 2018).

Similarly, common warthog MDP recorded in riparian forest of GCHA and HADCHA were not significantly different ($\chi2$ = 1.49, df = 1, P = 0.091) during the wet season and ($\chi2$ = 0.003, df = 1, P = 0.067) during the dry season. On the other hand, common warthog MDP recorded in open grassland of GCHA and HADCHA revealed significant variation ($\chi2$ = 11.6, df = 1, P = 0.054) during the wet season and insignificantly different ($\chi2$ = 0.89, df = 1, P = 0.083) during the dry season (Table 10).

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 *Combretum–Terminalia* habitats of both study areas during both seasons. This might be due to similar *Combretum–Terminalia* structure of Dabena Valley Forest in both study areas. But more proportion of common warthog population was recorded in riparian forest and open grassland habitats of HADCHA than GCHA. 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 (Abdu and Datiko, 2017).

On the other hand, the number of common warthog population in *Combretum–Terminalia* habitat was higher than in riparian forest and in 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 was contradicted with Abdu and 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 Mbirikani group ranch of the Amboseli ecosystem of Kenya. Rabira *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 in HADCHA 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 trees in GCHA than in HADCHA.

During the present study, *Combretum–Terminalia* habitat, riparian forest and open grassland habitat hosted more mean 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 study in grassland (13.44/km²) and comparable with the present finding in savanna woodland (5.65/km²) (Abdu and 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, stochastic process 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–death dynamics 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 in the three habitats showed insignificant variation during the wet and dry seasons in both study areas. This might be due to the tactic of hidings and pattern of movement of the animal in all habitats showed similarity.

Common warthogs were widely distributed in *Combretum–Terminalia* woodland, riparian forests and grazing lands in different degree along a transect lines in both study areas. *Combretum–Terminalia* had the highest common warthog, abundance, cluster density, sightings, followed by open grassland and riparian forests.

These vegetation zones empirically important for warthogs as a source forage, drinking and cover facilities. There were a seasonal variation in distribution, cluster density and sightings of common warthogs in all the habitats. Moreover, HADCHA had more population estimates, cluster density and encounter rate of warthogs than GCHA.

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