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ECOLOGY OF COMMON HIPPOPOTAMUS *(Hippopotamus amphibious, LINNAEUS, 1758)* AND CONFLICT INCIDENCE WITH HUMAN AROUND CHEBERA CHURCHURA NATIONAL PARK, ETHIOPIA

BY

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This is to certify that the thesis prepared by Aemro Mekonnen, entitled: Ecology of common hippopotamus *(Hippopotamus amphibious, LINNAEUS, 1758)* and conflict incidence with human around Chebera Churchura National Park, Ethiopia and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Biology (Ecological and Systematic Zoology) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

Ecology of common hippopotamus *(Hippopotamus amphibious, LINNAEUS, 1758)* and conflict incidence with human around Chebera Churchura National Park, Ethiopia

Aemro Mekonnen, PhD thesis, Addis Ababa University, 2019

An investigation on the distribution pattern, population size, feeding ecology, activity pattern and human-hippopotamus conflict at Chebera Churchura National Park (CCNP), Ethiopia was carried out from June, 2015 to October, 2018. The population estimate was carried out using total count. Activity pattern was investigated using scan sampling. Diet of hippopotamus was studied by collecting plant species identified from fresh feeding signs following the focal groups and was supplemented by faecal analysis. Feeding quadrat survey methods were employed to determine vegetation variable. Human-hippopotamus conflict was carried out by means of a questionnaire and focus group discussion. Habitat preference and suitability of hippopotamus were determined by using density of hippopotamus in the four different habitats during both seasons using multiple rings buffer analysis on Arc GIS 10.2. A total of 498 and 414 individuals of hippopotamus were recorded during wet and dry season resepectvely. The population size of this animal had no significant difference between river and lakes of Chebera Churchura National Park ($P>0.05$). Among counted individuals, 63.5% were adults, 20 % sub-adults and 16.5% young. Among adults, the male female ratio was 1:1.5. Larger herds of up to 30 individuals were observed during the dry season in major rivers and lakes where as smaller herds of a minimum of five individuals were seen during the wet season in temporary wetlands and swamps. The mean herd size during the wet and dry seasons was 9.20 ± 0.54 and 7.20 ± 0.45, respectively. During the wet season, larger proportion of hippopotamus (37.8%) was observed in the grassland. However, the dry season, most of the wetland in the open grassland dried up. This led to a shift in hippopotamus to the riverine forest (54.2%). From the total behavioural activities, resting comprised the largest proportion that accounts 38.89% followed by walking (27.24%). Barking and yawning events spent 52.18% and 47.82% of their time, respectively. Males spent more time resting than females, while females were more active. Feeding and moving peak activities were observed early morning and late afternoon hours with resting peak during the mid-day. Barking and yawning events mostly increased during the afternoon both in male and female hippopotamuses. Hippopotamus consumed a total of 40 plant species in CCNP. Of these, *Eriochloa fatmensis* (11.68%), *Typha latifolia* (9.91%), *Echinocloa pyramidalis* (9.59%) and *Cynodon dactylon* (8.45%) were the top four species of plants that contributed 39.63% of their overall diet. There were inverse correlations between sward height, greenness and cover with hippopotamus density. From questionnaire survey, 36.4% of respondents had negative attitude towards hippopotamus, while 55.9% and 7.7% had positive and neutral attitudes, respectively. Crop raiding, livestock damage and overgrazing were the major problems encountered resulting in conflict between human and hippopotamus in the study area. A total mean of 137 kg per household with a mean total cost estimation 1883 Ethiopian birr ($70) were lost due to hippopotamus. Prohibition of expansion of human settlements, awareness creation programme and participation of the local people for future conservation of the area is recommended.

Keywords: Activity pattern, Chebera Churchura National Park, feeding ecology, habitat association, human-hippopotamus conflict, population status

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DEDICATION

This work is dedicated to my family, who helped me from the beginning to the end of this research work

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ACRONYMS

CCNP	Chebera Churchura National Park
ENMSA	Ethiopian National Metrological Service Authority
EWCA	Ethiopian Wildlife Conservation Authority
HWC	Human-Wildlife Conflict
IUCN	International Union for Conservation of Nature and Natural Resources
IBA	Important Bird Area
WHO	World Health Organization

1. INTRODUCTION

1.1. Background and justification

Africa is endowed with a rich biodiversity (Mugabe, 1998). It is estimated to hold at least 25% of the global biodiversity. From a total of 5416 species of mammals, 21.2% occurr in Africa (Kingdon, 1997). African mammal taxonomy remains poorly studied and many new mammalian species are yet to be discovered (Afework Bekele and Yalden, 2013). Regardless of its rich biodiversity, however, African biodiversity is in sharp decline (Heller *et al*., 2012). During the last century five mammal species have become extinct in Africa. Currently, 84 out of a total of 175 species of large herbivores are classified as vulnerable, endangered or critically endangered (Gallina and Mandujano, 2009). Large African herbivores are currently confined to isolated protected areas which cover only 7% of the continent (Smitz *et al*., 2014).

Ethiopia is one of the richest countries in Africa in terms of its biodiversity (Afework Bekele and Yalden, 2013). Altitudinal variations from 116 m below sea level to 4,543 m asl, result in variety of ecosystems and diverse topography which enable the country to host wide range of wildlife species (Hillman, 1986; 1993). More than 320 mammalian species are recorded from Ethiopia, of which 55 are endemic (Lavrenchenko and Afework Bekele, 2017). Yet, many wildlife species face increasing threat of survival mainly associated with human impact across African countries (Wilson *et al*., 1996). While almost all ecosystems are affected by human activities, the rate of degredation is by far worse in the wetland habitats which are being degraded four times faster than the forest cover of the continent (François *et al*., 2005).

The wetland coverage, which is estimated to cover about 4 to 6% of the globe, is shrinking rapidly. It is estimated to have declined between 64-71% in the 20th century (Junk *et al*., 2013). The wetland loss in Africa is even worse when compared to the loss estimated globally as a result of exponential human population growth (Davidson, 2014; Dixon *et al*., 2016). Human population in Africa increased from 200 million during 1950 to 1.25 billion in 2018 (Altenburg *et al*., 2019) which in turn resulted to increasing agricultural farms and development including dams and irrigation schemes which affect natural habtiats including wetlands (Denny, 1994; Schuyt, 2005).

The loss of wetland has a huge implication both for biodiversity conservation and human life in general. Wetlands provide wide range of ecosystem services vital for human life including provisioning of food, freshwater, fibre and fuel, animal feed, medicinal plants, genetic material, income and house construction material, and transportation. It also regulates climate, water purification, retention of sediments and pollutants, flood and erosion, natural hazard, habitat for pollinators, culture (spiritual and inspirational, recreational, aesthetic and educational) and supports soil formation, nutrient cycling, and carbon sequestration and serve as migratory routes for animals and habitat for different flora and fauna (Kenter *et al*., 2011).

Wetlands have also a great biological significance in terms of harboring large biodiversity and many endemic, globally endangered or otherwise vulnerable wildlife species which need conservation focus. Various wetland types characterize the diverse and panoramic African environment, from mountains reaching an altitude of 6,000 m through deserts to coastal zones at sea level providing wide range of ecological zones for wide range of biodiversity forms. Many wetland species of birds, reptiles, amphbians and mammals including hippopotamus have a low range of tolerance for habitat loss and drying of their prime habitat, wetland (Timbuka, 2012).

In Ethiopia, wetlands cover nearly 2% (18,587 km^2) of the total land area of the country. With twelve river basins, eight major lakes and many swamps and floodplains, Ethiopia is one of the African largest wetland habitats that consititutes 45% of the African wetland (USAID, 2008). Ethiopia possesses of variation in the geological formation and climatic conditions which results in different wetlands across the different ecological zones and ecosystems, as alpine, fresh, alkaline-lakes, rivers and swamps (Lykun Abunie, 2003).

Ethiopian wetlands are extremely useful for biodiversity conservation and have a great potential for ecotourism (Mengistu Wendafrash, 2008). From the total of 73 hot spots which have been identified as Important Bird Areas (IBAs), 30 of these sites (41% of the total) comprise wetlands. Ethiopia is home for over 65 species of amphibian species where at least 26 of them are endemic to the country which is totally dependent on the wetland ecosystem (Mengistu Wendafrash, 2008). Yet, the Ethiopian wetlands shrink by 20% during the last 100 years (Hagos Gebresllassie *et al*., 2014). Consequently, wetlands in Ethiopia are regarded as vulnerable zones, and some even have lost their regenerating capacity and are at the verge of total damage (Hagos Gebresllassie *et al*., 2014). Lack of adequate knowledge and awareness of the social, economic and ecosystem benefits of wetlands and the increasing demand for agricultural land due to population pressure and degradation of upland areas are believed to be the most significant reason for increased conversion of wetlands to agricultural lands (Yohannes Afework *et al*., 2015). Traditional and modern agricultural expansion, continuous land degradation, urbanization and industrialization, lack of policies and institutional arrangements, lack of capacities, natural and ecological problems are the most dominant challenging factors of wetlands in Ethiopia (Hagos Gebresllassie *et al*., 2014).

The degredation of wetland causes a tremendous loss of biodiversity. Large number of wetland species is already extnict and others are on the verge of extinction (Urbye, 2006). Studies in biodiversity of wetlands receive little attention from researchers and data on the trends of biodiversity loss in the wetland is scant. From a better studied species, birds, a significant loss has been recorded. For instnace, a total population size of 380,000 lesser flamingos (*Phoenicoparrus minor*) in 1992 reported by Hillman (1998) was recently reported to decline to only 53,671 individuals (Tewodros Kumssa and Afework Bekele, 2014). While this is one particular case, several other species might have declined in a similar trend. Establishment of more protected areas is one of the conservation efforts aimed at protecting wildlife. Ethiopian Wildlife Conservation Authority (EWCA) has established more National Parks and protected areas to protect diverse habitat types and wildlife in these areas (EWCA, 2010; Afework Bekele and Yalden, 2013).

As habitats are degraded, wildlife species are urged to feed on the nearby crop of the local community which in turn results in human-wildlife conflict. Human-wildlife conflict used to occur globally since the origin of humans, but the conflict has escalated recently as humans took much of the area for agricultuare which previously was used by wildlife species (Lamarque *et al*., 2009). It is more intense in developing countries, where agriculture is an important component for the livelihood of the farmers (Boer and Baquete, 1998). The relative impact of wildlife damage on farm production varies depending upon the economic status of the community and the level of damage by wildlife species (Messmer, 2000). Mega-herbivores (weighing over 1000 kg, Owen-Smith, 1988), such as hippopotamus (*Hippopotamus amphibious*), Elephant (*Loxodonta africana*, Blumenbach, 1797), and large carnivores rank among the most problematic species and lie at the heart of human -wildlife conflict because they are dangerous to humans. The shrinking of wetland habitats also pushes some of the wetland mammals to forage on crops of the nearby farmers which in turn lead to conflict.

One of the wetland mammals of Ethiopia which is increasingly affected by human activities is hippopotamus (*Hippopotamus amphibious*). One of the largest wetlands in Ethiopia with large number of hippopotamus is Chebera Chuchura National park (CCNP). It is found in the South Nations and Nationalities. The Park is also the most protected with a promssing potential for conservation of hippopotamus and many other wildlife species including elephants, lions and many other flagship species (Demeke Datiko and Afework Bekele, 2013). As most of the wildlife protected areas of the country, the Park is surrounded by people and expanding agricultural activities (Abraham Megaze, 2006, 2015; Dereje Woldeyohannes, 2006). Except for a small number of larger mammals and birds, there is inadequate information about the total biodiversity of the area including hippopotamus.

Common hippopotamus is the third largest terrestrial mammal where the population size and distribution continues to decline across its range (Lewison and Oliver, 2008). Hippopotamus is regionally extinct in 5 African countries (Algeria, Egypt, Eritrea, Liberia and Mauritania) and near to extermination in Congo, Gambia and Somalia and it is currently categorized vulnerable by IUCN (Lewison and Pluháček, 2017). The most important threat for its survival is loss of its prime habitat, wetland, as a result of anthropogenic disturbance and livestock grazing.

Hippopotamus occur mostly along the western parts of the country (UNEP-WCMC, 2010). The species is abundant between altitudes of 200 and 2,000 m. The main strongholds are the Omo, Awash and Blue Nile rivers. Hippopotamus is also found in many of the larger lakes (Lake Tana, Lake Abaya, Lake Hawassa, Lake Langano, Lake Ziway and Lake Chamo) and isolated populations in smaller swamps and pools. The few that occur in the dry southeast area are confined to the Wabi Shebeli and Ganale Rivers. The northern limit of the species is the Setit River (Eltringham, 1999). Very few animals remain bordering Somalia although some small groups have been reported on the lower Shebeli River and along the Juba River (Eltringham, 1999; UNEP-WCMC, 2010).

Reliable estimates of abundance and understanding of the behavioural ecology and habitat requirement of a target species is crucial to guide the conservation management of vulnerable species (Acevedo *et al*., 2005). Unfortunately, very little is known on the population estimate and ecology of hippopotamus in Ethiopia (Eltringham, 1999; UNEP-WCMC, 2010). The level of enforcement of legal protection within Ethiopia in the wide range of the country̓s wetland is also unknown (Lewison and Oliver, 2008). According to Lewison and Pluhacek (2017) at present in Ethiopia about 2,500 individuals of hippopotamus may exist. Hence this study aims to determine the distribution pattern, population size, feeding ecology, activity pattern and human-hippopotamus conflict at Chebera Churchura National Park in western Ethiopia. This finding will provide primary information on the ecology of hippopotamus and its threat at CCNP in particular and in the country at large.

1.2. Signifcance of the study

The application and implementation of any conservation measure towards a species or habitat requires a scientific investigation (ecological study) of the target species and the habitat where it lives. Hippopotamus is a species which is highly dependent on pristine wetlands and which are productive ecosystems that support a diverse number of fauna and flora. Wetlands are the most important ecosystems in Ethiopia, supporting a wealth of flora and fauna, including many endemic plant species and several of Ethiopia's endemic or near endemic as well as threatened birds (IBC, 2009). However, they have been considered as less important compared to other ecosystems and they are under pressure. However, in order to evaluate the conservation status or understand the vulnerability to different threats on a species, it is vital to know the population size, distribution, activity pattern, feeding behaviour, its geographic range and movement, the rate of the population decline as well as habitat preferences and its interaction with its local people is worth knowing (Motsumi, ***et al*.,** 2007). But, the above points were lacking on the vulnerable hippopotamus population in Ethiopia, where it is crucial to design a biologically sound conservation strategy. Therefore, this study will provide detailed information on the ecological aspects of the species, which are fundamental requirements for the conservation of the species and the wetland habitat it depends

1.3. Objectives

1.3.1. General Objective

The main objective of this study is to assess the population status, distribution, habitat association, feeding ecology, activity pattern and human-hippopotamus conflict in Chebera Churchura National park (CCNP).

1.3.2. Specific objectives

- To determine the population size of hippopotamus in CCNP
- To describe the distribution and habitat association of hippopotamus in the area.
- To examine the activity pattern of hippopotamus in the study area.
- To investigate the feeding ecology of hippopotamus in the study area.
- To determine the level of human–hippopotamus conflict
- To examine the attitude of the local community towards wildlife and the Park.

1.4. Research hypotheses

- ❖ Habitat association of hippopotamus varies seasonally.
- ❖ Population size of hippopotamus varies between seasons.
- ❖ Behavioural activities vary between seasons, age groups, and sex of hippopotamus
- ❖ Hippopotamus consume higher proportion of grasses than browse in CCNP during both seasons.
- ❖ Crop damage was the main causes of human-hippopotamus conflict around and in CCNP

1.5. Research questions

- ➢ What is the current population status and distrubtion of hippopotamus in CCNP?
- ➢ What factors allow the persistence of hippopotamus in some habitats and not in others?
- ➢ What does the behavioural activity of hippopotamus look like in CCNP?
- ➢ How do local communities surrounding CCNP interact with hippopotamus?
- ➢ What are the attitudes and perceptions of people inhabiting near the Park about the presence or decline of hippopotamus and the implications of those attitudes for conservation?

2. LITERATURE REVIEW

2.1. Description of hippopotamus

Hippopotamus (*Hippopotamus amphibous*) is a large herbivores African mammal (Corbet, 1969). Hippopotamus is a common name for the two species of artiodactyl mammals that constitute the family Hippopotamidae, found only in Africa, one is common hippopotamus and the other is pygmy hippopotamus. Hippopotamuses are called river horses, and are heavy bodied, short legged, short-tailed animals, resembling pigs more than horses (Solomon Gebreyohanis, 2003). Their heads appear outsized and their mouths look unusually broad (Fig. 1), According to Lewison (2007), the origin of the Hippopotamidae has been a subject to inquiries for more than a century, and identifying the stem group of these mammals is also still a challenging issue for biologists (Olivier and Laurie, 1974). At present, kenyapotamines have been recorded only in Africa, in various Kenyan localities (Estes, 1992) and elsewhere in Africa. Taxonomically, Grubb (1993) lists five subspecies: *H. a. amphibious* from eastern Gambia to Sudan, Ethiopia, the northern Democratic Republic of the Congo (DRC), Tanzania and Mozambique, *H. a. tchadensis* from Nigeria and Chad, *H. a. kiboko* from Somalia and Kenya, *H. a. constrictus* from -Angola, the southern DRC and Namibia, and finally, *H. a. capensis* from Zambia southwards to South Africa. It is important to note, however, that this classification has not been widely accepted (Eltringham 1999; Beckwitt *et al*., 2016), furthermore, these five subspecies are visually indistinguishable in the wild, and the geographic extent of each range remains vague (Eltringham, 1993). Their morphology and diversity are now better described by Boisserie *et al*. (2005).

Pygmy hippos (Furstenburg, 2007)   Common hippos (Photo by: Aemro. M, Sep, 2017)

Figure 1.The two extant species of hippopotamus

Hippopotamuses have two essential requirements; water in which to submerge and nearby grassland for foraging (Jablonski, 2004). Their life span is between 35-50 years with animals in captivity living longer (Laws and Clough, 1966; Sayer and Rakha, 1974; Eltringham, 1999). Age at maturity for females has been estimated at nine to ten years (Millar and Zammuto, 1983; Graham *et al*., 2002). Sayer and Rakha (1974) recorded puberty and maturity for female hippopotamus at the age of seven and eight years, respectively, while in males, puberty started at six years and maturity reached at eight years (Sayer and Rakha, 1974).

Mating mainly takes place in water; females first conceive at about nine years (ranging between 7 and 15 years) and birth at two year intervals. Breeding in hippopotamus is not strictly seasonal (Estes, 1992), but most conceptions occur during the dry season and birth peaks during the wet season. Female hippopotamus have an average of 10-12 reproductive pregnancies during their lifetime (Lewison, 1998), with a gestation period of 6-8 months. An expectant female separates from the rest of the herd and keeps away for a couple of weeks. Calving occurs in shallow water or on land and a newborn is helped by the mother to the land (Sayer and Rakha, 1974). Normally, a single calf is born (Laws and Clough, 1966; Sayer and Rakha, 1974; Eltringham, 1999). Newborns are relatively small weighing about 25-55 kg (Sayer and Rakha, 1974; Eltringham, 1999). During this time, they become fiercely defensive and can be dangerous to people. They are also aggressive towards other hippopotamuses whether territorial males or her own grown offspring. Suckling of young takes place in water and on land. Lactation takes between 10-12 months, but some hippopotamuses have postpartum oestrus. A quarter of females examined during long term study in Uganda in the late 1950s to 1960s were pregnant and lactating (Laws and Clough, 1966). The young begins to eat grass at about three weeks but continues to suckle for a year. Generally, weaning takes place between six and eight months, with most calves being fully weaned by 12 months of age (Sayer and Rakha, 1974). Humans are the major predators of hippopotamus while lions, hyaena and crocodiles predate the young (Estes, 1992). Hippopotamus mainly defend themselves and attack using large, long, sharp lower canines (Estes, 1992).

2.2. Hippopotamus as a keystone species

Hippopotamuses are regarded as keystone species in river and lake habitats (Boisserie *et al*., 2011). They are an amphibious creature, spending the majority of the day in water, and emerging at night to feed on dry land (Eltringham, 1999). Subtropical floodplain forest, grassland and coastal grassland are especially important habitat types for this species. Thus, the ecological requirements for hippopotamus include a supply of permanent water, large enough for the territorial males to spread out at a depth of about 1.4 m (Taylor, 2013), and adequate grazing on open grassland within a few km of the daytime resting sites. Freshwater for drinking is essential when they live in a saline environment (Taylor, 2013). Although, they are restricted to regions in the proximity of water, they are able to disperse efficiently from one water source to another. Open water is not always essential as they can survive in muddy wallows but must have access to permanent water to which they can return in the dry season. The essential factor is that the skin must remain moist as it will crack if exposed to the air for long periods. A curious feature is the red secretion from modified sweat glands, which is thought to have an antibiotic function (Timbuka, 2012).

Wright (1964) argues very convincingly that the greatest benefit of an amphibious lifestyle is thermoregulation as a large body produces a considerable amount of metabolic heat. The water environment acts as a heat sink. Hippopotamuses leave their wallows soon after sunset and graze nocturnally on short grass swards up to several km from water. These swards, which are kept short by the grazing activities of the hippopotamuses, are known as hippopotamus lawns. Although they graze every night, except for mothers with very young calves, there are usually individuals present in the water all night, as some return after a few hours and others leave later. They consume approximately 40 kg of grass each night (Klingel, 1983), and may walk up to 35 km during these nocturnal foraging activities.

Ecologically, hippopotamus play an important role in the ecosystem. Grazing by hippopotamus may also influence plant community composition. Culling of hippopotamus in Queen Elizabeth National Park Uganda resulted in botanical changes such as decrease in grass basal cover, increase in bare ground and change in grass species composition, with tussock grasses such as *Sporobolous pyramidalis* increasing as a result of hippopotamus removal (Thornton, 1971).

Vegetation changes which may be associated with the combined effects of hippopotamus grazing and fire across other parts of Africa have also been reported by Olivier and Laurie (1974).

Feeding takes place on land at night followed by animals resting and digesting in water during most of the day. A large portion of ingested material is therefore defecated directly into water. Due to this tendency, hippopotamuses are considered as transporters of organic matter mediated through their gut (Eltringham, 1999; Grey and Harper, 2002; Spinage, 2012). The transported materials become available in a semi-processed form to aquatic consumers (Spinage, 2012). In DRC, decline of hippopotamus populations in Virunga National Park (Hart and Mwinyihali, 2001), resulted in decline of fish stocks because hippopotamus dung provide nutrients for fish.

2.3. Feeding ecology

Diets are extremely significant for determining evolution, life-history strategies and ecological role of animals (Mulungu *et al.,* 2011). Food is one of the most important dimensions of the niche. Therefore, information on diets of animals is virtually a prerequisite for most ecological research. Study of diets of animals is crucial for understanding relationships between species and between an animal and its environment (Hansson, 1999). These relationships may determine community structure, species diversity, relative abundance and resource partitioning among species and individuals.

Large mammalian herbivore species coexist by partitioning the key niche dimensions of diet and habitat (Schoener, 1974; Chase and Leibold, 2003). In areas where resources vary seasonally, the diet and habitat selection by large herbivores vary both temporally and spatially (Kleynhans *et al*., 2011, O'Kane *et al*., 2011). In tropical areas with wet–dry cyclic weather patterns, plant quality varies seasonally (Hopkins, 2000; Prins and Loth, 1988; Styles and Skinner, 1997). The wet season, when plants have low fibre and high nutrient concentrations, is the season with the highest quality forage for herbivores while the dry season, when plants invest more in structural carbohydrates and have their highest carbon: nitrogen ratios, is the season with lowest quality forage for herbivores . Therefore, in tropical areas where the year is divided into wet and dry seasons, large herbivores are challenged to satisfy their nutritional needs more during the dry season rather than the wet season.

Hippopotamuses have an enlarged, chambered stomach similar to ruminants (Arman and Field, 1973) although, unlike ruminants, they do not chew the cud (Eltringham, 1999) and hence are referred to as pseudo ruminants (Estes, 1992; Eltringham, 1999; Cerling *et al*., 2008). The pseudo ruminant stomach can effectively ferment grasses and other low quality foods (Arman and Field, 1973; Eltringham, 1999; Grey and Harper, 2002). In hippopotamus stomach, two anterior diverticula and a large median chamber are responsible for fermentative digestion while the posterior chamber secretes gastric juice (Arman and Field, 1973). Despite their watery environment, Hippopotamuses do not feed on aquatic vegetation to a great extent (Eltringham, 1999) and rather feed primarily on terrestrial vegetation (Eltringham, 1999; Grey and Harper, 2002; Cerling *et al*., 2008). Their diet consists mainly of grasses (Eltringham, 1999), however; some current studies have reported that they may feed on dicotyledonous plants to a significant extent (Boisserie *et al*., 2005; Cerling *et al*., 2008).

Recent studies using stable isotope ratios (13C/12C) have shown higher fractions of C3 (trees, shrubs and forbs) biomass than estimated from previous observations (Bocherens *et al*., 1996; Boisserie *et al*., 2005, Cerling *et al*., 2008), emphasizing that they are not strictly grazers. Mugangu and Hunter (1992) reported instances of hippopotamus in Virunga National Park in DRC Congo feeding more extensively on aquatic vegetation as a response to food shortage.

Mugangu and Hunter (1992) and Grey and Harper (2002) reported hippopotamus feeding on macrophyte aquatic vegetation to some extent in Lake Naivasha, Kenya, but aquatic plant form a negligible proportion of their faeces. Field (1970) reported hippopotamus eating the floating plants of the Nile cabbage (*Pistia stratiotes*) though it is unlikely that many were eaten. Holmes (undated) in the film titled “Hippopotamus out of water” by the BBC showed that during the dry season, Hippopotamus fed on sausage-like fruits (*Kigelia africana*), dried grass and leaves in Luangwa National Park, Zambia.

Seasonality and grazing are likely to affect the food resource available to hippopotamus. As with water availability, vegetation is an essential environmental resource for hippopotamus and is likely to affect their behaviour on temporal and spatial scales. Apart from water resources, vegetation has been listed as the other limiting factor for hippopotamus (Harris *et al*., 2008; Wilbroad and Milanzi, 2010; Chansa *et al*., 2011)

Hippopotamuses require aquatic habitat and forage primarily at night (TAWIRI, 2001). This leads to spatial and temporal constraints on their foraging behaviour (Lewison and Carter, 2004). Grass expansion in Africa during the Pliocene has been linked to success of early hippopotamus (Boisserie and Merceron, 2011). However, some current studies have reported that they feed on dicotyledon vegetation (Boisserie *et al*., 2005; Cerling *et al*., 2008; Harris *et al*., 2008). Mugangu and Hunter (1992) reported minor quantities of dicots in hippopotamus diet in Zaire (DRC) Grey and Harper (2002) reported hippopotamus feeding on macrophytes or aquatic vegetation when plant stands were abundant in shallow water in Lake Naivasha, Kenya. More studies in East and Central Africa and Lake Turkana in Kenya using stable carbon ratios (analysis of hippopotamus teeth enamel and hair tissues) showed a higher fraction of dietary non grass food materials in hippopotamus diet than estimated by traditional observations (Cerling *et al.*, 2008; Harris *et al*., 2008).

Hippopotamuses select short grassland for feeding (Lock, 1972; McCarthy *et al*., 1998; Harrison *et al*., 2007), mainly with swards less than 15 cm tall (Lock, 1972; McCarthy *et al*., 1998; Spinage, 2012) but are non-selective in terms of grass species they eat particularly during scarcity. Nevertheless, some studies have reported them as selective grazers (Chansa *et al*., 2011). They ingest both standing dried as well as green material (Meyer *et al*., 2005). Harrison *et al*. (2007) reported highest hippopotamus feeding intensity in areas with low growing grass in Malawi. Hippopotamus cannot forage in tall grassland because they are unable to chop and grind their food by gripping using their lips (Spinage, 2012). In Malawi highest grazing intensity was recorded by Harrison *et al*. (2007) in areas of flood plain and flood plain grassland with grass height at around 15 cm. There have been reports of carnivory in hippopotamus (Dudley, 1998). However, these are reported as rare and are thought to be fulfilling a nutritional need of hippopotamus as vegetation often lacks essential nutrients or trace elements (Eltringham, 1999; Grey and Harper, 2002). Hippopotamuses have a lifestyle which is energy-efficient and thus eat about 40 kg of grass a night which is only 1-1.5 % of their body weight (Eltringham, 1999; Grey and Harper, 2002; Clauss *et al*., 2007). It has been reported that Hippopotamus employ foraging strategies that respond to vegetation characteristics such as vegetation quality, quantity and distance to water source (Lewison and Carter, 2004).

Hippopotamuses begin to commute to inland pastures shortly before dark, along branching paths up to 3-5 km long, up to a maximum of 10 km (Estes, 1992; Eltringham, 1999). After grazing for up to five hours, they return to the shelter before dawn (Estes, 1992). Though when feeding hippopotamuses are solitary, young calves and sub-adults accompany their mothers, remaining with them until almost full grown at about 6-8 years. Females with new born young remain in water for several days for protection of a calf against possible attacks from predators.

2.4. Adaptation of hippopotamus to its aquatic environment

Hippopotamuses are amphibious and this has a fundamental effect on their physiology and way of life (Eltringham, 1999). Water is required for their thermoregulation and animals are thus never found far from water (Cerling *et al*., 2008). They are well-adapted to aquatic life (Cerling *et al*., 2008; Herbison and Frame, 2008) which makes them unique in Africa among the large mammals (Eltringham, 1999; Cerling *et al*., 2008). Studies using oxygen isotope ratios (18O/16O) have shown that hippopotamuses are the most oxygen-depleted mammals, which directly reflects to their semi-aquatic habitat (Bocherens *et al*., 1996; Cerling *et al*., 2008).

Hippopotamuses have also unique skin consisting of a thin epidermis with no sweat glands. And as a result, they lose water much more quickly than other mammals (Jablonski, 2004). Out of water, they risk rapid dehydration and overheating in hot weather (Estes, 1992). They must therefore retreat to water to keep their bodies cool because they do not sweat (Eltringham, 1999). Their skin is almost hairless and they do not have sebaceous glands, but have mucus secreting glands which produce a thick oily pink fluid which helps to keep their skin moist (Saikawa *et al*., 2004). Although the fluid secreted is not strictly sweat, because it is produced by sub-dermal glands (Eltringham, 1999), it acts like sweat in helping to control body temperature. It is also thought to have antiseptic properties (Eltringham, 1999). The secretion is alkaline with pH 8.5-10.5 (Saikawa *et al*., 2004) and with two pigments; red and orange. The pigments act as sunscreen and have antibiotic function because, even at lower concentration, they can inhibit the growth of pathogenic bacteria *Pseudomonas aeruginosa* and *Klebsiella pneumonia* (Saikawa *et al*., 2004) and shield hippopotamus from harmful ultraviolet rays. Their core body temperature is around 36°C (Luck and Wright, 1959; 1963; Cena, 1964; Noirard *et al*., 2008) and in order to reduce sun exposure, they have to move in to water and bath when environmental temperatures increase.

The large and wide head of the hippopotamus has eyes, nostrils and ears set on the top, allowing them to partly submerge. Hippopotamus can swim and dive well and their negative buoyancy allows them to walk along the bottom of water. When they are completely submerged their slit-like nostrils and ears are sealed off (Estes, 1992; Eltringham, 1999). As an adaptation to its aquatic environment, the feet are hoofed with membranes stretching between each of the four toes, helping the hippopotamus to move through water. The fat beneath the skin is also an adaptation to its watery environment, making this large animal buoyant enough to float easily. Young hippopotamus can suckle under water by taking a deep breath, closing the nostrils and ears and wrapping their tongue tightly around the teat. They are reported to suckle in the same way while on land. While in water, newborn calves can climb on the back of their mother to rest.

2.5. Behavioural ecology of hippopotamus

Hippopotamuses are highly gregarious and are territorial only when in the water (Olivier and Laurie, 1974; Estes, 1992). Males defend territories against other bulls but only if they challenge the incumbent male. Territories are established to defend mating rights rather than food which explains why they are non-territorial away from water. Females are non-territorial and are not necessarily confined to a single territory, although most return to the same area of water after grazing. A territorial system is not obvious and general mixing of individuals of all ages and both sexes can give the impression that territories are not held (Olivier and Laurie, 1974), however, more intensive studies have confirmed hippopotamus territoriality (Klingel, 1991).There are no social bonds between the adults within a group despite the fact that hippopotamus lie in close contact with each other. The social bonds are between the mothers and daughters, but males form separate bachelor groups (Lewison, 2007).

2.6. Distribution and trend of hippopotamus population in Africa

Historically hippopotamus occupied an extensive range in Africa and were considered abundant. Although the species still occurs widely throughout the continent, its dispersion is patchy and uneven HSG (1993) and Eltringham (1999) estimated the total population of Africa at about 157,000 animals of which 7,000 occurred in West Africa, 70,000 in East Africa and 80,000 in Southern Africa. These estimates were based on questionnaires and information for several countries was not available, including Angola. Moreover, HSG (2004) place the continental population between 130,000 and 155,000. Except for the Zambian population which appears to be increasing, hippopotamuses are stable or declining in all of the 36 countries included in the census. Of the 36 countries where the common hippopotamus is known to occur, 20 have confirmed declining populations, seven have populations of unknown status, nine have stable populations and five are regionally extinct (Algeria, Egypt, Eritrea, Liberia and Mauritania) and near to extermination in Congo, Gambia and Somalia (Lewison and Pluháček, 2017).

According to HSG, 1993 and HSG, 1994 in West Africa, hippopoptamus exist in small relict populations isolated from each other and are most abundant in estuarine habitats and the lower reaches of rivers, with a few occurring in the sea. The largest numbers are in Guinea, Guinea Bissau and Senegal (-7,000). The group of countries comprising Ivory Coast, Ghana, Togo, Benin and Burkina Faso has perhaps 2,000 hippopotamus, Nigeria and Niger a further 500 and Cameroun, Central Africa Republic, Equatorial Guinea, Gabon and the Congo are unlikely to contain more than 2,500 altogether. However the recent estmation by Lewison and Pluháček (2017) the over all population is approximately 7,500 spread over 19 countries.Within the region, most abundant in Cameroon and Burkino Faso.

In East Africa, surveys have been carried out in a number of countries. Estimates for the Selous Game Reserve in Tanzania were 15,483 in1986, 24,169 in 1989 and 20,589 in 1990 (Games, 1990). Several thousand hippopotamus occur elsewhere in Tanzania. In Uganda the main concentrations are in Queen Elizabeth (Ruwenzori) and Murchison Falls National Parks. In the early 1950s the Queen Elizabeth Park population numbered 21,000 but this was reduced to some 14,000 through culling. The population was further reduced by heavy illegal hunting during the Idi Amin regime and was counted at about 2,000 animals in 1989. The Murchison Falls population suffered a similar fate and numbers are now similar to those in Queen Elizabeth Park. Regionally, the largest populations of hippopotamuses are found in Tanzania. Recent estimates from Ethiopia suggested that hippopotamuses occur from the Djibouti border through the highlands to the south and south west; Current estimates for Ethiopia are 2,500 and no hippopotamus found in Ertriea(Lewison and Pluháček, 2017)..

Southern Africa contains the largest numbers of hippopotamus on the continent– some 80 000 animals. The major part of the population lies in a belt extending across the region between latitudes 15º- 25º south of the equator. The potential exists, through the development of transfrontier conservation areas, for the subpopulations in the countries within (Wilbroad and Milanzi, 2010).

In countries such as Zambia, hippopotamus population surveys conducted between 2005 and 2008 are showing some improvement in their population size (Wilbroad and Milanzi, 2010). Zambia has the highest population size of any African country (Lewison, 2007; Lewison and Oliver, 2008). The coarse estimate for the region is 60,000 (Fig. 2).

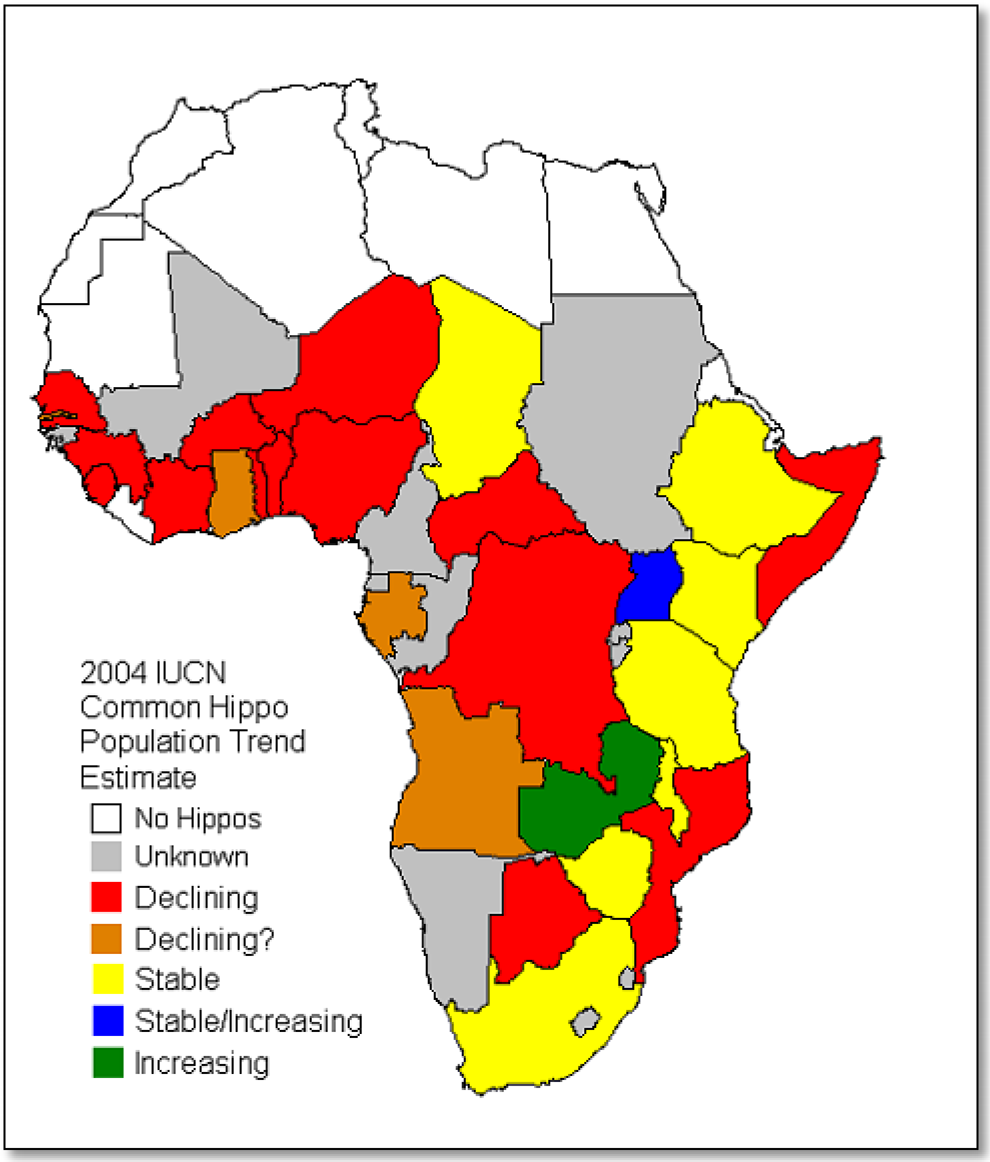


Figure 2. Population trends of hippopotamus in Africa (Source: Lewison and Oliver, 2008)

2.7. Distribution of hippopotamus in Ethiopia

Hippopotamus occur in Ethiopia within the western parts of the country (UNEP-WCMC, 2010). Hippopotamus occur from the Djibouti border through the highlands to the south and southwest, with the main threat reported to be habitat loss, degradation, and unregulated hunting. Earlier hippopotamus census found the main strongholds to be the Omo, Awash and Great Abbay (Blue Nile) and Gibe River. Hippopotamuses are also found in many of the larger lakes (Abaya, Hawassa, Langano, Ziway, and Chamo) and isolated populations in smaller swamps and pools. The northern limit of the species is the Setit River. One of the largest hippopotamus populations is found in Dhati-Welel National Park, a newly protected area in May 2012. Very few animals remain in neighbouring Somalia (*ca*. 50) although some small groups have been reported on the lower Shebeli River and along the Juba River. Current estimates for Ethiopia are 2,500 (Lewison and Pluhacek, 2017)

Based on previous pilot studies, there will be a larger population of hippopotamus in Ethiopia even if they are facing a growing threat of extermination from habitat loss. With the country huge potential of wetland, there may be still large population of hippopotamus not reported yet. Hippopotamus is registered as Vulnerable by IUCN (Lewison and Pluháček, 2017). As its range in many African countries, the wetlands in Ethiopia face increasing threat of drying up as a result of unregulated over-utilization, including water diversion for agricultural intensification, urbanization, dam construction, pollution and other anthropogenic interventions.

With increasing demand of water for human use, industries, irrigation for agriculture, livestock grazes and siltation from erosion the wetlands in Ethiopia and across other African countries are drying up threatening aquatic mammals including hippopotamus. Hippopotamuses are also subject for hunting by humans for food. Hippopotamuses are one of the least studied species, and the population estimate given even by IUCN is mainly on adhoc observations and short term studies. Most of the country reports used are also 17 years old assessments which may not represent the current situation. Hence, contemporary study on the population size, distrubtion, behavioural ecology and interaction with humans in the protected area of hippopotamus is timely.

2.8. Human-Wildlife conflict

Conservation of wildlife is in crisis as species are declining worldwide. The major causes of declines in wildlife in developing countries are human population growth, habitat fragmentation, inadequate land use practices and management, lack of economic alternatives, social and political conflicts, and unsustainable use of resources (Fitzgibbon *et al*., 1995; Burkey, 1997; Myers *et al*., 2000; Kideghesho *et al*., 2007; Plumptre *et al*., 2008). The magnitude of these threats is greater in areas where a large proportion of human population relies directly on natural resources to sustain livelihoods (e.g. bush meat, for ivory or trophies) (Fitzgibbon *et al*., 1995; Kideghesho *et al*., 2007; Plumptre *et al*., 2008). An increase in human population around the protected areas results in competition for resources between human and wildlife (Peterson *et al*., 2010; White and Ward, 2011). Livestock and agriculture are basic in the livelihood of rural people in developing countries (Boer and Baquete, 1998) and mostly escalate human-wildlife and wildlife-livestock competition for resources (de Garine-Wichatitksy *et al*., 2013).

Human-wildlife conflict is one of the current challenges facing conservation efforts in developing countries where wildlife is declining as a consequence of social factors such as human population pressure, food security, land use practices and poverty. It becomes acute when the local substitute resources become scarce for both humans and wildlife (Decker *et al*., 2002; Madden, 2004; Packer *et al*. 2006; Marshall *et al*., 2007; Gusset *et al*., 2008). Apart from poaching, there are other interactions between hippopotamus and humans where they live in close proximity and interfere on activities of one another (Post, 2000). Hippopotamus damage crops and fishing equipment and, endanger the lives of humans although the level of impact varies from one region to another (Eltringham, 1993; Post, 2000; Martin, 2005; Lewison, 2007).

Crop damage is a widespread and common problem across sub-Saharan region (Maples *et al*., 1976). Crop damage in Africa by potentially life threatening species such as hippo, buffalo, rhino, warthog, and elephant resulting in unique dilemma (Naughton-Treves, 1998). These animals can be extremely dangerous to hunt by 'traditional' methods (snares and spears) and farmers can also be killed trying to defend their crops against them. These species are generally perceived by people as property of the state. The state institutions responsible for protected areas are, therefore, considered responsible for these animals, and the institutions are generally ill-equipped to overcome the problem and are blamed for losses to crops and property. Rural farmers for the most part attend their crops. The problem escalates when an animal, wounded by snares or spears, ultimately kills a person (Monaghan and Wood-Gush, 1990). Hippopotamus grazing along riparian areas will facilitate some herbivore species and cause competitions with others. In addition, hippopotamus grazing will influence predation risk for herbivores, as the cover of tall vegetation increases with distance from rivers, with varying effects on different herbivore foraging guilds. The dry seasons will further force herbivores to congregate close to rivers, amplifying habitat stress especially in the pastoral ranches grazed heavily by livestock. Herbivores use of the riparian habitats in the pastoral ranches will be constrained by human presence and livestock herding. Herbivores that are more water dependent and require high food quality will decline with distance from rivers. Herbivores that are bulk feeders will increase with distance from rivers. Herbivores that are less water dependent will be uniformly distributed relative to distance to rivers.

Mega-herbivores (weighing over 1000 kg, Owen-Smith, 1988), such as hippopotamus, Elephant and large carnivores rank among the most problematic and lie at the heart of human-wildlife conflicts because they are dangerous to humans. Substantial information on human-hippopotamus conflicts is scattered in office files and thus less widely accessible. Hippopotamus differ from other mega-herbivores in having a dual requirement of daily living space in water and an open grazing range often visited at night (Eltringham, 1999). This requirement affects the manner in which hippopotamus utilize resources and survive in areas dominated by high human population densities and continuous land use changes. While most studies on human wildlife conflicts have concluded that conflicts are intense at the periphery of protected areas (Naughton-Treves, 1998; Saj *et al*., 2001), this may not necessarily be true for hippopotamus since they inhabit wetlands that often extend outside protected areas into agricultural landscapes.

Being mainly wild grazers (Cerling *et al*., 2008), hippopotamus destroy crops cultivated close to wetlands (Mkanda and Kumchedwa 1997; Eltringham, 1999) and pose physical threats to local communities. However, like most other hippopotamus-range states in Africa, Ethiopia has done little to evaluate the type, extent and consequences of human-hippopotamus conflicts, even though local communities report numerous complaints on hippopotamus damages regularly. Substantial human-induced environmental changes pose a serious challenge to biodiversity conservation (Cincotta *et al*., 2000; Thaxton, 2007). It is probable that significant proportions of threatened and vulnerable species of conservation concern, like the hippopotamus (Lewison and Oliver, 2008), rely on or utilize agricultural landscapes and experience conflicts with humans (Siex and Struhsaker, 1999; O'Connell-Rodwell *et al*., 2000; Tourenq *et al*., 2001; Green *et al*., 2005). Therefore, to effectively address human wildlife conflicts, it is necessary to consider both the effects of damage caused by wildlife as well as the impacts of mitigating actions on the conservation status of target species.

Attitudinal studies are increasingly being adopted as tools for evaluating public understanding, acceptance and the impact of conservation interventions (Anthony, 2007; Ramakrishnan, 2007). This is because; understanding local community attitude about conservation is the key to improve the protected areas-people relationship if protected areas are to achieve their goals (Oli *et al*., 1994; Weladji *et al*., 2003; Mekbeb Eshatu *et al*., 2010). Many factors influence the conservation attitudes of local people positively or negatively. The magnitude of the resultant effects of each particular factor is determined by the historical, political, ecological, socio-cultural and economic conditions and this may call for different management interventions (Mehta and Heinen, 2001; Ormsby and Kaplin, 2005; Ryan *et al*., 2015). The understanding of all these factors is important to improve the relationship between local residents and protected areas. In the present study area, increasing demand of the use of Park resource, wildlife imposed constraints and socio demographic factors (age, gender, education level, and religion and occupation) were the possible reasons in shaping local people attitudes. The behaviour, cultural values and attitudes of people can influence and impact the success of conservation interventions, particularly in areas where wildlife may affect people's assets. Thus, conservation of biodiversity has to involve the assessment of people's attitudes to develop a site-based "conservation strategy" which involves multiple stakeholders to integrate wildlife needs and human livelihood aspects (Decker *et al*., 2002; Riley *et al*., 2002; Madden, 2004; Kideghesho *et al*., 2007)

3. MATERIAL AND METHODS

3.1. Study area descreption

3.1.1. Location of the study area

Chebera Churchura National Park (CCNP) is located along the southwestern part of Ethiopia. The name of the Park was obtained from the two main Kebeles around the Park (Chebera and Churchura). It is partly located within Dawro zone (Churchura) and in Konta special district (Chebera), and located at about 370 km from Hawassa (the capital of the region) and 590 km from Addis Ababa (Fig. 3). The Park is located between $35^0$55’00’’ and $36^0$57’17’’E latitude and $6^0$56’05’’ and $7^0$08’02’’N longitude within the western side of the central Omo Gibe Basin. It has an estimated area of 1250 km^2 and is bounded by Konta Special Wereda to the north and west, Omo River to the south, Dawro Administrative Zone to the east and southeast (Fig. 3). There are five small crater lakes which are distributed in different parts of the Park area. The altitude of the area ranges from 550 to 1700 m asl at the volcanic peaks of the western boundary. The highest peak is at Mecha hill on the western boundary (Girma Timer, 2005; Dereje Weldeyohanes, 2006; Demeke Datiko, 2013 and Aberham Megaze, 2015). It is characterized by few flat lands and highly undulating to rolling plains with incised river and perennial streams, valley and gorges. The climate of the study area is characterized by a relatively hot climatic condition. The prominent topographic feature of the CCNP is highly undulating terrain that is interspersed with different valley floors and hills, There are perennial and seasonal rivers that rise from nearby highlands and flow into the Park (Girma Timer, 2005; Aemro Mekonnen *et al.*, 2018).

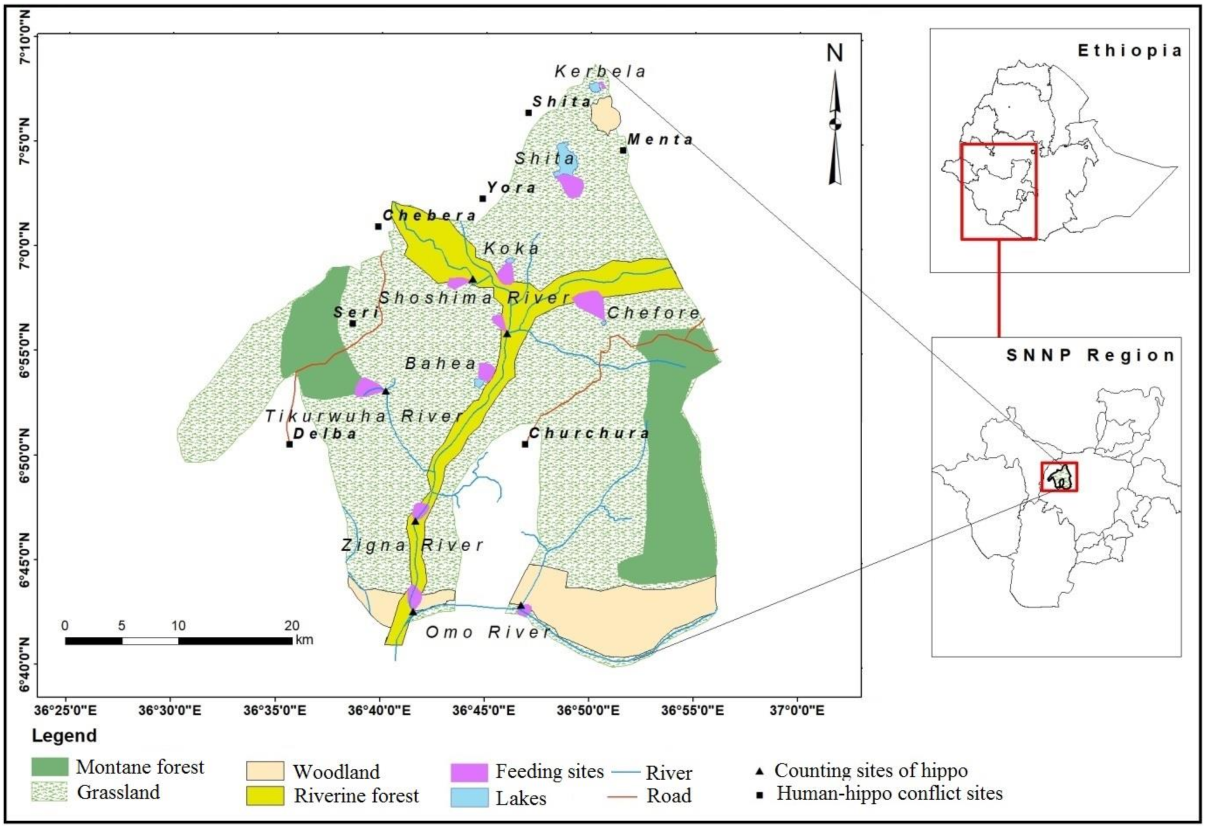


Figure 3. Map of the study area (Chebera Churchura National Park**)** and sample sites

3.1.2. Topography and hydrology

Chebera Churchura National Park is characterized by a unique and highly heterogeneous hilly terrain. Large portion of the study area is highly undulated interspersed with different valley floors, drained bottomland with different hills. The study area lies at the centre of the Omo-Gibe River Basin. The highlands are characterized by steep slopes. The lowlands, by contrast, are characterized by low altitude and relatively gentle slope (Girma Timer, 2005; Dereje Weldeyohanes, 2006). Five smaller crater lakes are distributed in different parts of the Park area. The altitude of the area ranges from 550-1700 m asl at the volcano peaks in the western boundary (Girma Timer, 2005) as shown in (Plate 7).

There are five small and medium sized lakes (Shita, Keribela, Koka, Chefore and Bahea) located at southeast, west, northwest and north of the Park. The area has many rivers (Shoshima, Zigina, Mensa and Tikurwuha) and their tributaries drain the area. The tributaries are many in number during the rainy season but dry during the dry season. These rivers join the Dawro zone of the

Park, then flow to Omo River, that bounds the Park at the southern boundary. There are also several hot springs in different parts of CCNP (Plate 6)

3.1.3. Climate

Chebera Churchura is characterized by a relatively hot climatic condition. The rainfall distribution is unimodal. The average amount of annual rainfall in the area varies from 1000 to 3500 mm. The 10 years rainfall data (2008 to 2018) of the area is given in Figure 4. The area has uniform and long rainfall season (between March and September and with a peak in July). The dry season of the study area is from November to February, with mean maximum temperature varying between 27 and 29^{o}C. The hottest months are January and February while, the coldest months are July and August with the mean maximum and minimum temperatures of 28^{0}C and 12^{0}C, respectively (Dereje Weldeyohanes, 2006).

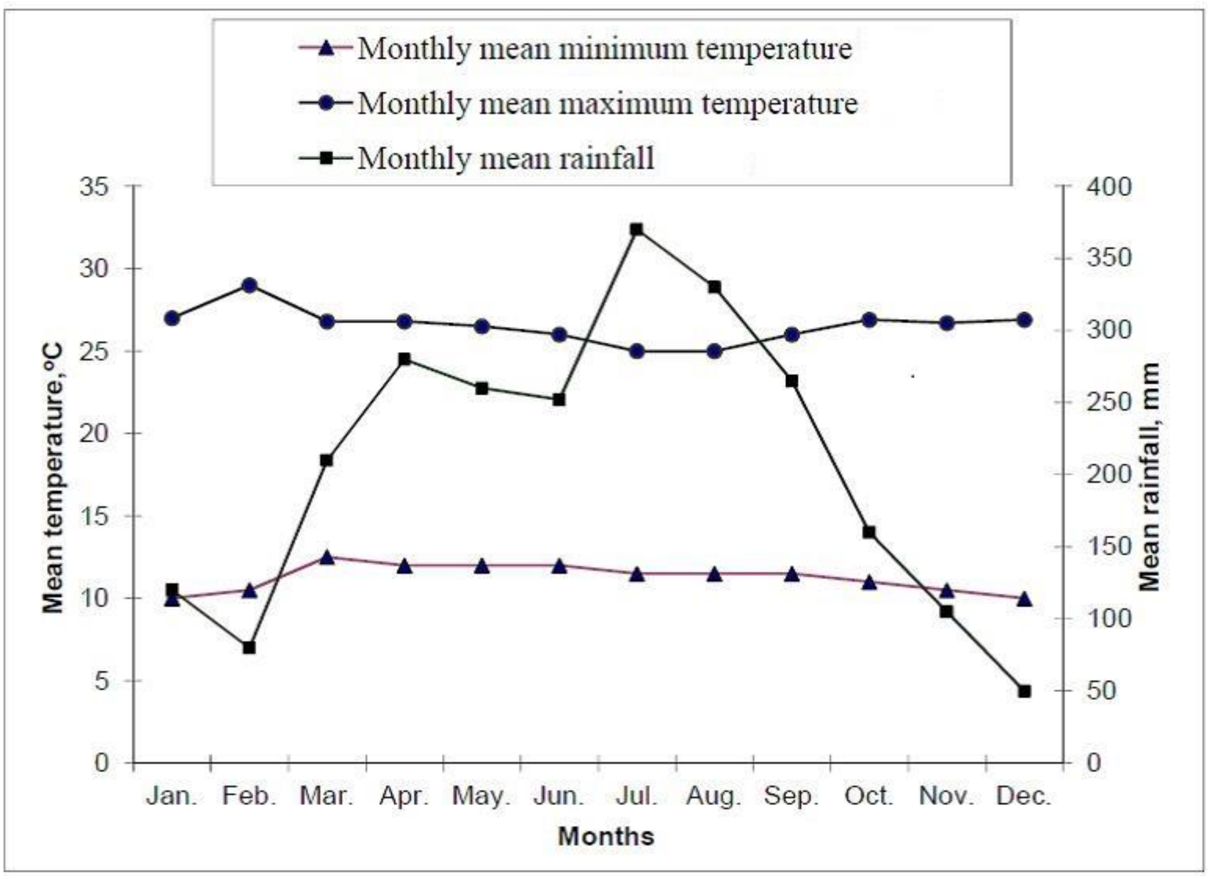


Figure 4. Mean monthly temperatures and rainfall of CCNP from 2008 to 2018 (Source: Ameya Wereda)

3.1.4. Socio-economic status

The principal ethnic groups found around CCNP are Dawro and Konta Nationalities. Other minority groups include Tsara, Menja and Bacha. Dawro ethnic group inhabits the eastern highland and few areas of the southeastern lowlands areas. These people do not make extensive use of the lowlands except along the periphery. Konta ethnic group occupies the north and northwestern highland areas. People of the Churchura Peasant Association inhabit the southern lowland. The Konta Koisha and Delba Peasant Associations occupy the southwestern lowland area, adjoining the study area. Recently, there are people from Hadia and Wolaita ethnic groups inhabiting the area through government resettlement programme in the southwestern part of the surrounding Park.

Mixed agricultural practices are the sole livelihood of the majority of the inhabitants around the study area. The people practice traditional agricultural system that combines perennial and annual cultivation with livestock rearing. Thus, the land-use practice is predominantly traditional shifting cultivation and livestock rearing. Shifting cultivation is common in the south and southwestern lowland on the undulating and rolling plains by residents around the study area. Once farmed, the area is abandoned for 3-5 years without cultivation. This land use system is more serious especially in and around forest reserves close to human settlements. Permanent crops harvested in the area include cereals, fruits, enset and vegetables. Enset, sorghum and maize are the major staple crops, and mainly used for household subsistence. Coffee and honey are the major income earning products of the study area. A wide range of fruits and vegetables are also cultivated both for subsistence and for sale. Teff is cultivated mainly for cash (Dawro Zone Report, 2004, Girma Timer, 2005). The minority groups of people also lead their livelihood by collecting and selling wild honey, spices, and wild coffee and edible roots from the forests of some of the wild plants (Dawro Zone Report, 2004). Hence, forests are important economic sources for the local people besides their ecological value.

3.1.5. Fauna and habitat description

The Park harbours different species of of mammals and birds over 39 large mammalian species are found (Adane Tesgaye *et al.,* 2017) in CCNP. Most of these mammalian species are common in the forest habitats. The Park is believed to possess good diversity of birds, fish, reptiles and amphibians. A total of 137 bird species was also recorded from the Park (Dereje Weldeyohans, 2006) and 16 species of rodents and 2 species of insectivores were also recorded

(Demeke Datiko and Afework Bekele, 2013) also recently two mammalian species, *Weyns duiker* (*Cephalophu swensi*) and *Harveys duiker* (*Cephalophu harveyi*) were recorded in this park which were not officially recorded in Ethiopia before (Mezmer Girma, 2014). The Park is also the only home in the world for an endemic species of fish called Gara Chebera which is named by Chebera Kebele of the National Park (Mezemer Girma, 2014)

The range of habitats in the CCNP is diverse in both altitude and vegetation cover. Description of the vegetation type was made following the habitat classification scheme of White and Edwards (2000) and as described by Girma Timer (2005). The natural vegetation of CCNP is highly diverse and dominated by various plant species. About 106 woody plant species were identified by a single survey of which Six (*Millitia ferugeni Vepris daneli*, *Solanecio gigas*, *Cussonia ostini*, *Erythrina burcei* and *Rhus glutinosa*) are endemic to Ethiopia (Mazmer Girma, 2014). Habitats of CCNP are classified as Montane forest, Riverine forest, Woodland with scattered trees and Grassland areas.

1. Montane forest: This type of vegetation occurs in the eastern and north western highlands of the study area. It is dominated by tree species and characterized by the crown cover of 50%. The structure is multistoried (WBISPP, 2002). Climbers and saprophytes are important floristic components of the habitat. Under normal conditions, the distribution of trees through this forest area is relatively uniform. The dominant tree species are *Podocarpus*, *Juniperus* and broad-leaved tree species (Fig. 5a).

2. Riverine forest: This type of vegetation occurs along the course of the river of the study area. It covers about 40 km^2. The major rivers in the study area are Zigna, Shoshima, Wala, Tikurwuha, Mensa, Oma and other small seasonal rivers or streams. This habitat is characterized by mixed vegetation type composed of large trees and herbaceous species. The dominant plant species are *Ficus*, *Phonex*, *Costa*, *Albizia grandibracteata*, *Chionantus mildobradii*, *Grewia ferrugunea*, *Aspilia mosambicensis*, *Arundo donax* and *Ehretia cymosa* (Fig. 5b) (Adane Tesgaye *et al.*, 2017).

3. Woodland: Woodland covers 8% of the total study area. Based on the types of dominant species, the woodland area can be characterized as mixed and *Combretum* woodlands. The *Combretum* woodland, which is found along the southern part of the area, is characterized by the dominant species of Combretum and Terminalia species. It is also common in low-lying valley areas bellow 1100 m asl. This type of woodland has an even distribution of trees, uniform canopy, almost no understory of bushes or shrubs, but typically with a well-developed grass cover. The other type of the habitat is mixed woodland, dominated by mixed species. It occurs in the northern upland area next to highland drainage and a break between highland and lowland. They are commonly burnt every year. Riparian woodland is found along many of the drainages in the lower or the southern part of the study area near to the Omo confluence. This vegetation type has a clear tree grass formation without additional stories. Dominant plant species are *Acacia brevispica*, *Maytenus arbutifolia*, *Vitex doniana*, *Terminalia brownii*, *Combretum colinum* and *Combretum mole* (Fig. 5c) (Adane Tesgaye *et al.*, 2017).

4. Grassland with scattered trees: This habitat covers the largest part of the study area and belongs to the Sudanian-Biome regional centre of endemism. It covers 62.5% of the total area and is widely distributed in parts of the Park area. It is characterized by extensive grass species with few dominant scattered trees. The dominant grass species in most distributional range of this habitat is the elephant grass (*Pennisetum sp*.). The scattered trees that occur in this habitat are resistant to fire. They have thick and gnarled bark. The dominant tree species are broad-leaved *Combretum* species in association with *Terminalia albiza* (Fig. 5d). The local people in search of grazing land and clear site deliberately set fire (Adane Tesgaye *et al.,* 2017)

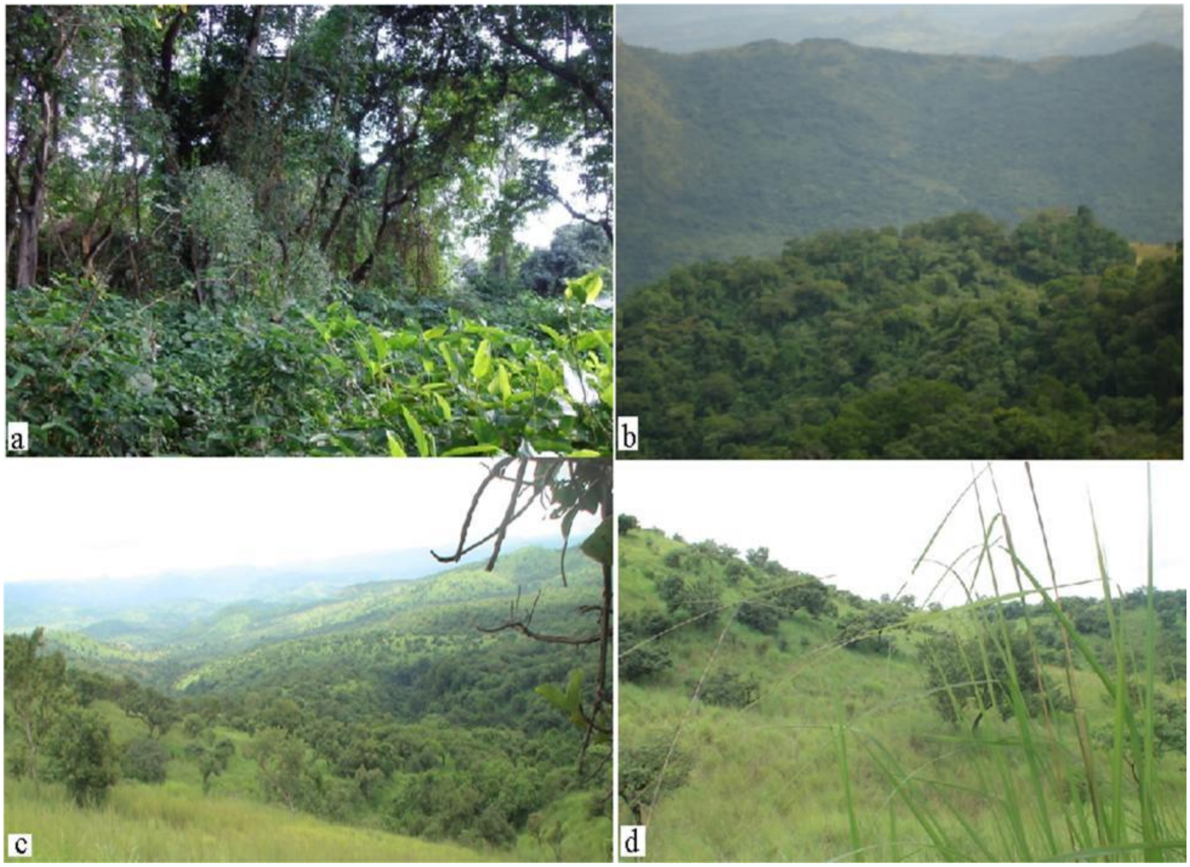


Figure 5. Different vegetation types in CCNP, ideal for hippopotamus (Photo By: Aemro. M, May, 2017). (a) = Riverine forest, (b) = Montane forest, (c) = Woodland, (d) = Grasslands with scattered trees

3.2. Materials

Materials like, GPS, binoculars, camera, video camera, night trap camera, hip-chain, sward stick, Oven, steel meter tape, data sheets, topographic map of the area and its surroundings (1: 50,000 and 1: 250,000), SPOT image of 2017, DEM (digital elevation model), Google Earth images and pictures and other necessary field gears were used for this study.

3.3. Methods

To get precise plans of data collection including selecting three focal groups to conduct ecological studies and selecting farmlands for human wildlife conflict, a preliminary study was carried out from May to October 2015 and the main date were collected from September 2015 to February 2018 . Rivers, lakes and major wetlands were identified with knowlagable Park scounts and mapped using ArcGIS. Habitat types (riverine forest, grassland, montane forest and woodland) were identified on the basis of ground truth and 30 m LANDSAT image and google earth images. For the human-hippoptamus conflict study seven villages were selected on the basis of distance of villages to the main hippopotamus sighting areas (Naughton-Treves, 1998; Naughton-Treves *et al*., 1998). To have a preliminary idea on the extent of the conflict, and determine if the local community collaborates in answering quesitonary survey, 56 adult individuals were interviewed. This result is not included in the main sample group study. Climatic variables including temperature and rainfall for over 10 years period was also obtained from Woreda meterology station located 15 km from the CCNP during this pilot study.

3.3.1. Population size and structure

Population estimates were carried out in 5 creator lakes (Shita, Keribela, Koka, Chefore and Bahea) and 4 major Rivers (Shoshima, Zigna, Tikurewuha and Omo, Fig 6, Table 1) during day time when the hippopotamus were still in the water. The lakes were usually small in size except Shita (average 35 hectares, Table 1). In the small lakes and all rivers, the count was carried out by walking over one side of the lake or river from north to east aided with binoculars (Tembo, 1987; TAWIRI, 2001). In Shita where the hippopotamus can not be counted with one team due to large size of the lake, counts were carried out by two teams walking on opposite sides of the lake simultaneously. Whenever hippopotamuses were observed at the centre of the lake, to avoid double counting the two teams communicated for the sightings of hippopotamus around the centre of the lake and only one team rigstered the count.

In every count event, at least four observers were deployed to count independently. Average number of hippopotamus per day was calculated and monthly means were`derived. The total counts were carried out during both wet and dry season for two replicates in each season for both lakes and rivers. The surveys were performed twice a day, in the morning (08:00 to 12:00 a.m.) and in the afternoon (14:00 to 18:00 p.m.) when hippopotamuses are most visible as they are active and clumped in groups (Martin, 2005).

During the total count, sex and age composition of every hippopotamus sighting was recorded. Sexes of the animals were determined by body size and sexual dimorphic features, while age classes were determined based on body size and their positions and external features. This follows the method used by Tsi *et al*. (2011) and Chomba (2013). Individuals were classified as young and adult based upon age. Average size of herds observed in different lakes and rivers during wet and dry seasons were taken to compare the distribution of hippopotamus in different habitat types, following the methods of Norton-Griffiths (1978).

During each count, the location of each of the herd was recorded using GPS and MAPPED using ArcGIS (Lewis and Wilson, 1979). Individuals were considered as a member of the same herd if the distance between them was less than 50 m (Borkowski and Furubayashi, 1998), responded in a related manner to external stimuli and if moved in the same direction with the rest of the members of the herd.

Table 1. Counting site of hippopotamus in Chebera Churchura National Park

Counting Site	Area/hectare	Type	Buffer zone
Bahea	47	Lake	Riverine forest
Koka	15	Lake	Grassland
Chefore	10	Lake	Grassland
Kerebela	68	Lake	Woodland
Shita	300	Lake	Grassland
Shoshima	240	River	Riverine forest
Zigna	320	River	Riverine forest
Tikurwuha	190	River	Montane forest
Omo	287	River	Riverine forest
Total	1477		

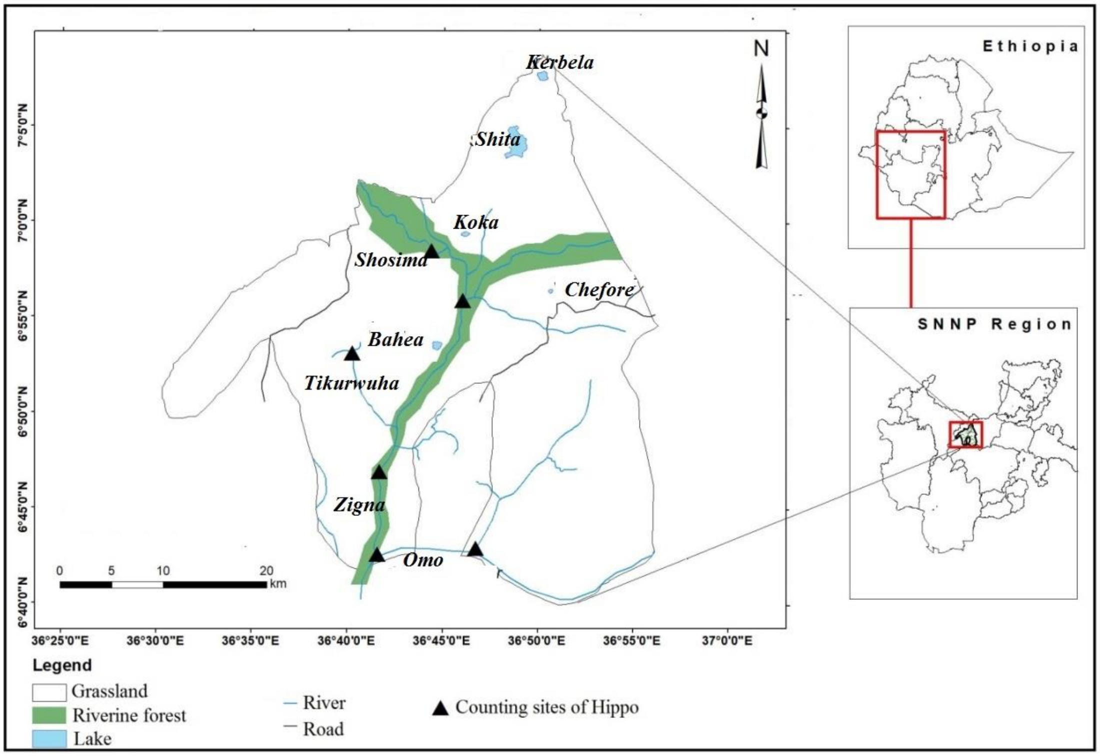


Figure 6. Counting site of hippopotamus in Chebera Churchura National Park

3.3.2. Distribution and habitat suitability

During every count, the type of habitat types (riverine forest, grassland, montane forest and woodland) where hippopotamuses were sighted was recorded. The habtiats were classified by combining images of 30 m resolution LANDSAT, and Google earth and shape file created from GPS records on the boundries of each habitat from ground truth data. Since it was diffecult to cover all lakes and rivers, Lake Kerbela and Shita were selected to determine the habitat suitablity based on the relative large size and nearer to human settlement and livestock disturbance. According to Wengström (2000), distribution and habitat use of hippopotamus depend on the habitat suitability of the nearby buffer zone and this buffer zone depends on three major factors. These are grazing ground proximity, lake shore elevation and slope and human settlement and livestock disturbance Grazing ground suitability on the basis of proximity to resting water and settlement, and livestock disturbance was classified and reclassified using multiple rings buffer analysis on Arc GIS 10.2. The slope class which helps hippopotamus movement to the land was identified based on literature and field observation (Dietz *et al*., 2000) (Table 2).

Table 2. Suitability classes for each criteria/factor of hippopotamus habitat

Criteria	Suitability class			Source
	Highly suitable	Moderately suitable	Not suitable	
Slope and elevation	1634–1900 m	1900 –2000 m	>2000 m	Dietz *et al*. (2000)
Grazing land proximity	2–5 km	5–10 km	>10	Wengström (2009)
Settlement disturbance	5.5 km	3 km	0.5 km	Tracy (1996)

Rivers and lakes were surrounded by one of these habitats determining the availability of forage. Habitat preference of the hippotamus was determined on the basis of density of the hippopotamus in four different habitats during both seasons (Larson *et al.* 1978, Norton-Griffiths, 1978). Some habitats consisted of much larger density of hippoptamus compared to others indicating habitat preference (Larson *et al.*, 1978, Norton-Griffiths, 1978). Conducting the study during both wet and dry seasons was important to determine the habitat preference of the hippopotamus seasonally as vegetation cover changes substantially during wet and dry seasons

3.3.3. Activity pattern

Activity pattern was studied by focal watch on three focal groups by scan sampling at 5 minutes interval from 07:00 to 18: 00 h. Focal animals were identified by distinctive morphological characteristics (skin mark or skin colour). The focal groups have the same sex and age composition with a total of 6 individuals, 3 adult females, 2 adult males and 1 young. The focal watch was carried out between January and April, 2017 for the dry season and between May to August, 2017 for the wet season. Observations were made for five consecutive days for eight months. Behavioural activities were recorded as resting, standing, walking, feeding and socializing while barking and yawning recorded as behavioural events at five minutes interval during wet and dry seasons (Massana, 1993). These behavioural categories were defined as behavioural activities and events. Behavioural activities had relatively longer duration which includes: Resting, Standing, Walking, Feeding and Socailizing (Martin and Bateson, 2007; Timbuka, 2012). Events are behavioural patterns of relatively short duration such as vocalization or discrete body movements including Barking and Yawning (Martin and Bateson, 2007) (Table 3).

Table 3. Major behavioural activites and their description adopted from (Martin and Bateson, 2007; Timbuka, 2012).

Behaviour	Description
Resting	Lying on the water bank or on land without leg movements. At this state, they were immobile and may be passively touching each other
Standing	Staying stationary with no or very limited leg movements
Walking	All activities on land involving leg movements, except when feeding, including searching for feeding sites
Feeding	Head movements associated with cutting and ingesting food
Socializing	Touching, sexual, biting, rolling, ear flicking and splashing
Barking	Shouting and aggressive fighting
Yawning	Frequnt opening and closing of the mouth

3.3.4. Feeding ecology

The plant species consumed by hippopotamus were studied by examination of fresh feeding signs following focal groups at close distance (Theophile *et al.*, 2012). The food plants, bitten or plucked by the animal, were collected, pressed and identified with the help of a taxonomist in the Botanical Herbarium in Addis Ababa University. The percentage of feeding preference of a plant species was determined by summing its frequency of biting or feeding sign observation divided by sum of frequency of all plant species collected at feeding sites multiplied by hundred throughout the study periods (equation 1) (Theophile *et al.*, 2012). CSi= $\frac{FSi}{\sum_{i=1}^{n} FSt}$ X 100 Where $= \sum_{i=1}^{n} Ft$=the total frequency of all collected species.

Feeding observation method was supplemented by faecal analysis (Landman and Kerley, 2001; Macandza *et al*., 2004; Paola *et al*., 2005) to examine foraged species. Dung piles were collected from different habitats and air-dried before faecal analysis (MacLeod *et al*., 1996). Faecal samples of the same season of a year were amalgamated to form composite samples (Homolka, 1987; Katona and Altbacker, 2002). Composite samples were broken up by hand and washed repeatedly with water on 0.1 mm sieve to remove finely digested food fragments (Buys, 1990). Then samples were added into a beaker, treated with 75% alcohol and left for 48 hours. Domestic bleach was added after decanting alcohol and left until bleached (Williams, 1969; Ellis *et al*., 1977). The samples were washed with water and stained with safranin and left for 2 days

(Ellis *et al*., 1977) before microscopic examination. Five slides from each composite faecal sample were examined using compound light microscope. A small amount of the prepared faecal sample was spread on gridded slide and counted at ×100 and ×40 power of magnification (Bartolome *et al*., 1998). Counting and identification of epidermal 80 fragments were aided by reference slides (Morrison, 2008) and morphological features such as cell shape, venation and trichomes (Morrison, 2008). Fragments identified to the species level were classified as graminoids, herbs and dicots (Gaylard and Kerley, 1995; Prins *et al*., 2006), and those which are not identified were grouped as unknown.

Grass height was measured in the first week of each month, on random plots designed in two steps. First, at each habitat types, quadrats of 100 x 100 m were randomly selected. Second, in each of the plots, subplots of 10 plots of $1m^2$ were laid on a random basis and height of the grass was measured at the four corners results a total of 160 height measurements. The grass height was measured using a sward stick, a calibrated 1.5 m metal rod in a 30 cm diameter disc made of aluminium sheet with a hole at the middle for sliding the disc along the metal rod. In each quadrats of 100 x 100 m, the numbers of hippopotamuses were counted (Payne *et al*. 1993). Correlation analysis was carried out based on the number of hippopotamus and average grass height of the quadrat. Average sward height was obtained by calculating the mean of the forty corners of the ten $1m^2$ quadrats (Théophile *et al*., 2012; Timbuka, 2012)

Vegetation cover was measured within the same quadrat used for sward height measurements while sampling sward height; percentage coverage of vegetation was estimated within the quadrat's 1 x 1 m area. This was done visually by estimating the proportion of the quadrat covered vegetation and bare ground (Théophile *et al*., 2012; Timbuka, 2012).

Sward greenness (green vegeration cover) was estimated within the same quadrat used for sward height measurements. Sward percentage greenness in the quadrat was estimated visually by observing and estimating the contribution of green vegetation to vegetation in the quadrat (Timbuka, 2012).

Plant biomass and standing dried biomass were measured by cutting, drying and weighing the vegetation in three replicates measuring 25 x 25 cm quadrats in each site. Quadrats were positioned at random within 100 x 100 m sampling area. All vegetation in each quadrat was clipped. Within each quadrat, only stems that emerged from within the quadrat area were included in the sample. Plant litter and any other material that was not rooted in the quadrat were removed. Thereafter, all attached stems were clipped at soil level and divided into green, live stems and standing dried stems. Stems were classed as living if 5% or more of their surface appeared green. Any herbaceous, non-grass species were sampled and kept separately.

Living stems, standing dried stems and other species were bagged separately and kept in labeled paper envelopes and air dried for 10 days. Envelopes were stored in a dry place before oven drying at 60^oC to constant weight and then weighing to the nearest 0.01 g on a Mettler top pan balance. Results were expressed as means of the three replicate quadrats scaled to per m^2. A total of 60 quadrat samples were collected over the study period (Théophile *et al*., 2012; Timbuka, 2012).

3.3.5. Human- hippopotamus conflict

Human-hippopotamus conflict was carried out by a questionnaire and focus group discussion modified from Newmark *et al.* (1994) and Maddox (2003). The study was carried out in seven villages (Chebera, Serri, Yora, Shita, Menta, Churchura and Kerbela) selected during the pilot study (Fig. 7) ranging from 0 to 5 km apart from the boundary of the Park and near to the major water bodies where the hippopotamus occured. The questionnaire was administered to 256 households (about 20% of the total number of households (1280 houshold)), of which 159 (62%) were males and 97 (38%) were females. The questionnaire was designed to understand the situation of human–hippopotamus conflict towards the conservation challenges in the area. The survey assessed the attitudes of people towards hippopotamus. The questionnaire survey provided for each of the household focused on the following main questions, i) Information on the respondents demographic data (age, sex), ii) Whether hippopotamus damage their crops, kill livestock and humans the type of crops damaged, and the frequency of hippopotamus visiting their farmland per week iii) if the crop damage is reported, throughout the farming period (v) common cultivated crops; (vi) local knowledge of the respondents on the presence of hippopotamus and the trend in their population size through 5 years ; (vii) protection measures adopted to protect crop damage ; (viii) attitudes of people towards hippopotamus and the Park management; (ix) what benefits the local people get from the Park; and (x) the level of awareness about the value of wildlife in general and hippopotamus in particular. Data were collected using a semi-structured survey design, following a similar format to that used by Maddox (2003). The questionnaire was administered to farmers within their area of farming and/or residence (Hill, 2000) at a random manner based on first come first serve basis (Newmark *et al*., 1994).

Focus group discussion and open-ended responses were also held in the villages to discuss the experience in the human-hippopotamus conflict and to collect information on knowledge about wildlife in the area (Plate 1). During group discussion, 18 kebele leaders and knowledgeable people were participated in the disscussion and the researcher initiated the discussion by stating some of the observations and responses from people interviewed and from questionnaires. Participants were allowed to state their views or suggestions on risks, conflicts, how conflicts are resolved and what should be done to mitigate those conflicts. The Park staffs and Kebele leaders also took part in the discussion to provide information on the impact of hippopotamus on the local people in the Park. Group discussion was used as a complement for the questionnaires.

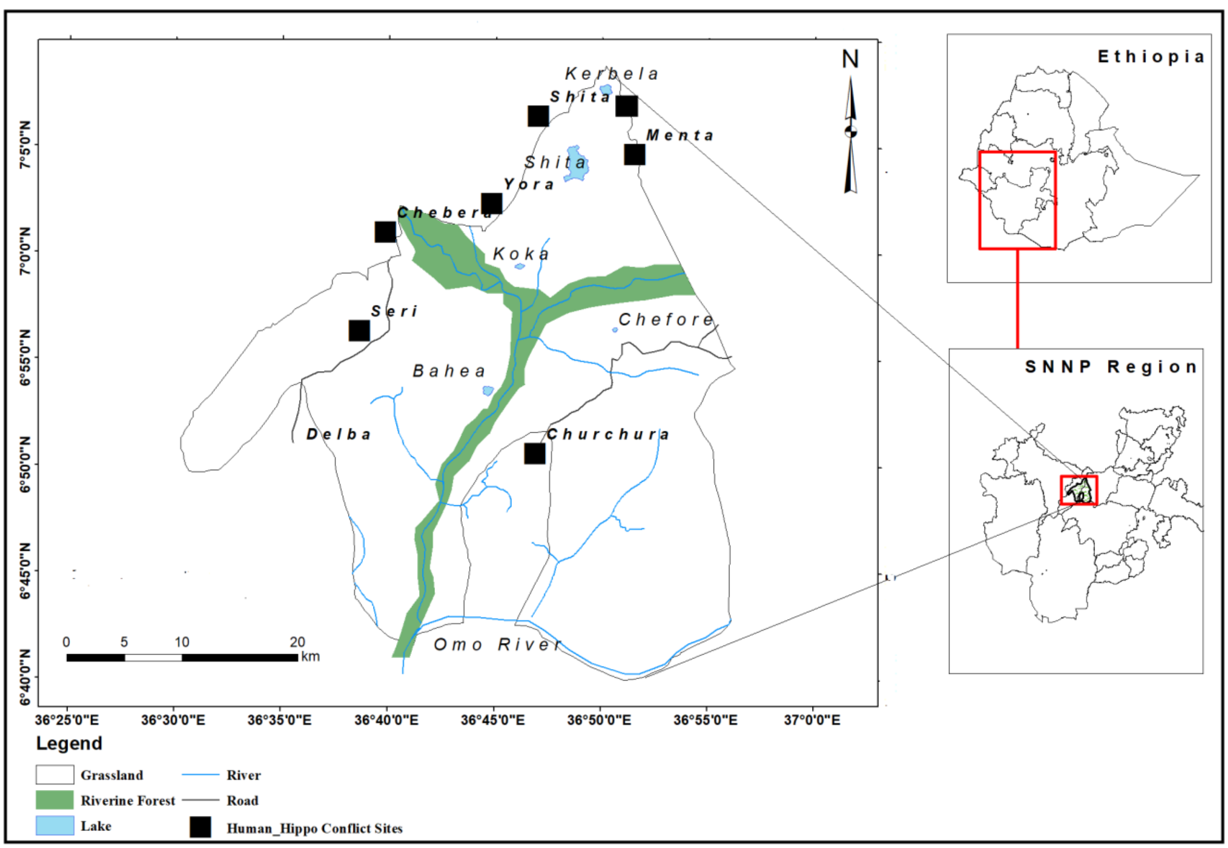


Figure 7. Map of CCNP showing the locations of surveyed villages

To estimate the crop damage by hippopotamus directly, five sites (Chebera, Kerbela, Shita, Menta and Serri were selected and the extent of damage for each crop was recorded. Five farming lands were selected randomly and visted every three days for five occasions. The area of the farming land under surveliance was measured and divided in to 5 grids of 6470 m^2 each. The crop types used for assessment were Maize, Wheat, Enset, Teff, Banana, Potato and Sorgham. Farming lands were visited every three days and crop damage was recorded in addition for other issues information. The grids consisted of areas with sown crops like the damaged portions were estimated directly in m^2. The distance of the crop field to the Park was also recorded (Naughton-Treves, 1998). For each of the crop types, 5 farmlands were selected randomly and 4 m^2 area of the crop collected and measured. For cereals, a possible harvest per kg was calculated. For fruits and vegetables, the average harvest per tree was estimated. After the crop damage was estimated, the loss was calculated based on the assumption what the damage could produce if it was harvested as matured and the estmation was converted into dollar bases.

3.4. Data Analyses

Different statistical tools such as IBM SPSS version 20, Microsoft excel and PAST Version 3.15 was used for analyses. One way ANOVA were used to compare the population size of the study animal in CCNP. Multiple rings buffer analysis on Arc GIS 10.2 was used to analysis habitat suitablity. Population structures were tested using t-tests. Pearson Correlation Coefficient (r) was used to test the relationship between vegetation and population density of hippopotamus and to test the relationship between feeding observation survey and faecal analysis methods**.** Chi-square tests for selected variables were used to determine the degree between dependent and independent variables and to test the significance of some sociological parameters and attitudes of local communities towards the hippopotamus. Data from individual interviews and focus group discussions were described using textual analysis method. 0.05 level of significance used as the criterion for comparison of the mean and confidence interval at 95%.

4. RESULTS

The findings of this study are presented in five separate sections. The first section deals with the population size and structure of hippopotamus in the study area. The second part is about the distribution and habitat association of hippopotamus in CCNP. The third section deals with activity pattern of hippopotamus. The fourth part deals with feeding ecology of hippopotamus in CCNP and the fifth is on human-hippopotamus conflict around the Park and attitude of the local community towards conservation areas and wildlife in the Park.

4.1. Population size and structure

The total mean population size of hippopotamus estimated in CCNP was 456±32 individuals, and the mean population density estimated was 0.31individuals/ha. The population estimates of hippopotamuses for wet and dry seasons were 498±43 and 413±21 individuals, respectively. There was a significant difference in the number of animals counted during the two seasons (χ^2 = 35.5, df =1, P<0.05). More hippopotamuses were seen during the wet season than during the dry season (Table 4).

Table 4. Population size of hippopotamus in Chebera Churchura National Park during wet and dry season (Mean±SE)

Season	Lakes	Rivers	Density/ ha	Population size
Wet	314.61±35.61	183.50±7.17	0.34±0.32	498.11±42.8
Dry	255.73±32.98	157.42±8.22	0.28±0.54	413.15±21.2
Mean	285.17±34.29	170.46±7.70	0.31±0.43	455.63±32

During 2016/2017, an average of 457±3.88 individuals was estimated from during dry and wet seasons (average of 413±28.8 and 501±29.9 individuals in dry season and wet season, respectively (Table 5). During 2017/2018, an average of 455±53 individuals were estimated (an average of 414±50.2 and 496±56 individuals for dry season and wet season respectively (Table 6).

Table 5. Population size of hippopotamus in different lakes and rivers of Chebera Churchura National Park during 2016/2017 (Mean± SE)

Counting site	Area / ha	Buffer zone	Dry season	Wet Season	Mean	Density/ha
Bahea	47	Riverine	75±3.60	77.51±4.55	76.25±4.07	1.62±0.08
Koka	15	Grassland	44.5±5.67	57±7.17	50.75±6.42	3.38±0.42
Chefore	10	Grassland	44.5±5.67	53.5±5.12	52.62±7.56	5.26±0.75
Kerbela	68	Woodland	40.5±6.80	69±5.52	54.75±6.16	0.80±0.09
Shita	300	Grassland	51.5±6.34	63.5±1.5	57.5±3.92	0.19±0.01`
Shoshima	240	Riverine	34.1±1.58	36.25±0.43	35.17±1.00	0.14±0.01
Zigna	320	Riverine	60.50±0.51	62±1.41	61.25±0.9	0.19±0.03
Tikurwuha	190	Montane	21.5±0.86	34.75±0.75	28.12±0.80	0.14±0.04
Omo	285	Riverine	40.75±3.19	47.75±3.19	44.25±3.19	0.15±0.01
Total/Average	1475		412.8±28.80	501.26±29.6	457.03±3.78	0.31±0.15

Table 6. Population size of hippopotamus in lakes and rivers of Chebera Churchura National Park during 2017/2018 (Mean± SE)

Counting Site	Area /ha	Buffer Zone	Dry Season	Wet season	Mean	Density/ha
Bahea	47	Riverine	71±7.90	78±3.67	74.5±5.78	1.58±0.12
Koka	15	Grassland	44.25±6.79	59.75±13.08	52±9.93	3.46±0.66
Chefore	10	Grassland	45.75±10.20	60.25±12.11	53±11.15	5.30±1.12
Kerbela	68	Woodland	43.75±5.88	59.75±13.98	51.75±9.93	0.76±0.15
Shita	300	Grassland	50.75±7.11	51.50±4.55	51.12±5.83	0.17±0.02
Shoshima	240	Riverine	35.5±2.50	38.75±1.90	37.12±2.2	0.15±0.01
Zigna	320	Riverine	60.25±2.27	63.25±3.26	61.75±2.76	0.19±0.01
Tikurwuha	190	Montane	21.5±2.95	36.5±2.29	29±2.62	0.15±0.01
Omo	285	Riverine	40.75±4.60	47.75±1.08	44.25±2.84	0.16±0.01
Total/Average	1475		413.94±50.2	495.5±55.91	454.72±53.1	0.308±0.23

The density of hippopotamus in the wetland of CCNP is 0.31 individuals /ha. Lakes have a larger density of hippopotamus, 0.65 individuals/ha compared to rivers (0.16 individuals /ha). However, statically there is no significant variation at F=3.94, df=1 p 0.088 level of significance. As shown in Table 7, Lake Chefore has the highest number of individual 5.28 individuals /ha followed by Koka 3.42 individuals /ha. The relative abundance of hippopotamus in different lakes of CCNP in the wet and dry seasons showed highly significant variation (χ^2= 14. 35, df = 4, P<0.05).

Table 7. Density of hippopotamus in lakes of CCNP

Lakes	Area/ ha	Dry season	Wet season	Mean	Density/ha
Bahea	47	73±5.75	77.75±4.11	75.37±4.92	1.60±0.10
Koka	15	44.37±6.23	58.37±10.12	51.37±8.17	3.42±0.54
Chefore	10	45.12±7.93	56.87±8.61	52.81±8.27	5.28±0.93
Kerbela	68	42.12±6.34	64.37±9.75	53.25±8.04	0.78±0.12
Shita	300	51.12±6.73	57.5±3.02	54.31±4.91	0.18±0.01`
Total/Average	440	255.73±32.98	314.61±35.61	285.17±34.29	0.65±0.34

Hippopotamuses had a higher density at the open, slow and deep site of the river mostly along the river bed side, and not distributed uniformly across the rivers. Density of hippopotamus varied in the river. The relative abundance of hippopotamus also varied significantly during the wet and dry seasons (χ^2 = 6.91, df = 2, P < 0.05) (Table 8).

Table 8. Density of hippopotamus in the major rivers of CCNP

Rivers	Area/ ha	Dry season	Wet season	Mean	Density/ha
Shoshima	240	34.8±2.08	37.50±1.17	36.14±1.60	0.15±0.01
Zigna	320	60.37±1.39	62.62±2.35	61.50±1.83	0.19±0.01
Tikurwuha	190	21.5±0.86	35.63±1.52	28.56±1.71	0.14±0.01
Omo	285	40.75±3.89	47.75±2.13	44.25±3.01	0.16±0.01
Total/Average	1,035	157.42±8.22	183.50±7.17	170.45±8.15	0.16±0.01

Age and sex composition of hippopotamus for a total mean population of 456 individuals, is shown in Table 9. Among counted individuals, 63.5% were adults, 20 % sub-adults and 16.5% young. Among adults, 26.1 % were males and 37.5% were females. Out of adult individuals, male and females represent 40.8% and 59.2% respectively. Females are by far larger than males (t= 2.646, df= 4, P= 0.038). The number of adult females were significantly higher than young (t= 2.661, df = 4, p = 0.037). Adult males were also significantly more than young (t=2.5, df = 4, p= 0.047). The sex ratio of adult male to adult female was 1:1.5. Young to adult individual ratio was 1.00:5.21. But, young to adult female ratio was 1.00:3.09.

Table 9. Age and sex ratio of the observed hippopotamus population during wet and dry seasons (Mean+ SE) (AM=Adult Male, AF=Adult Female, SAM=Sub-adult Male, SAF, Sub Adult Female, Y=Young, O =Other)

Age structure and sex ratio			
	Season		
Categories	Wet	Dry	Mean
AM	136.5±1.5	101.1±2.5	118.8±2.0
AF	182.7±1.5	159.4±1.0	171.1±1.25
SAM	33.8±2.5	26.5±1.0	30.1±1.75
SAF	55.4±3.0	66.6±2.5	61.0±2.62
Y	89.6±2.0	60.4±2.0	75.0±2.0
Ratio			
AM:AF	1.00:1.34	1.00:1.57	1.00:1:45
SA:A	1.00:3.58	1.00:2.79	1.00:3.18
SA: O	1.00:4.58	1.00:3.44	1.00:4.01
Y: O	1.00:4.56	1.00:5.85	1.00:5.21

The mean number of herd and the mean herd size of hippopotamus varied seasonally (Table 10) During the dry season, most of the wetland dried up leading to have a large herd near to large lakes and rivers. In contrary, during the wet season, the wetland increased dramatically due to rainfall and flood from rivers and lakes providing wide habitat for hippopotamus leading them to disperse over large range. While the number of herds declined to 7.20 during the dry season from

9.42 herds of the wet season, the number of individuals within the herd during the dry season (25.36 individuals ± 0.24) was significantly larger (χ^2 = 39.1, df =1, P<0.05) than wet season (10.76 individuals ± 0.28, (Table 10). The mean number of herds varied significantly seasonally (χ^2 = 42.5, df =1, P<0.05).

Table 10. Number of herds and herd size of hippopotamus observed during the wet and dry seasons (Mean+ SE) of the study period.

Season	No of Herd	Herd size
Dry	7.20±0.45	25.36±0.24
Wet	9.42±0.54	10.76±0.28
Mean	8.31±0.49	18.06±0.26

4.2. Distribution and habitat association

In CCNP, lakes and rivers provide a total of 1475 ha water bodies. The hippopotamuses however, were concentrated along the water bodies in open, slow moving and sufficient water that enabled them to submerge their large body size and get their forage on nearby side of the rivers/lakes. As the multiple rings buffer analysis depicted that the most suitable area for nocturnal grazing for hippopotamus is preferred to be close to resting water. Therefore, by keeping other factors constant and taking the capability of hippopotamuses to move and forage, only 42% of estimated area was classed as highly suitable and 58% area was moderately suitable (Fig. 8).

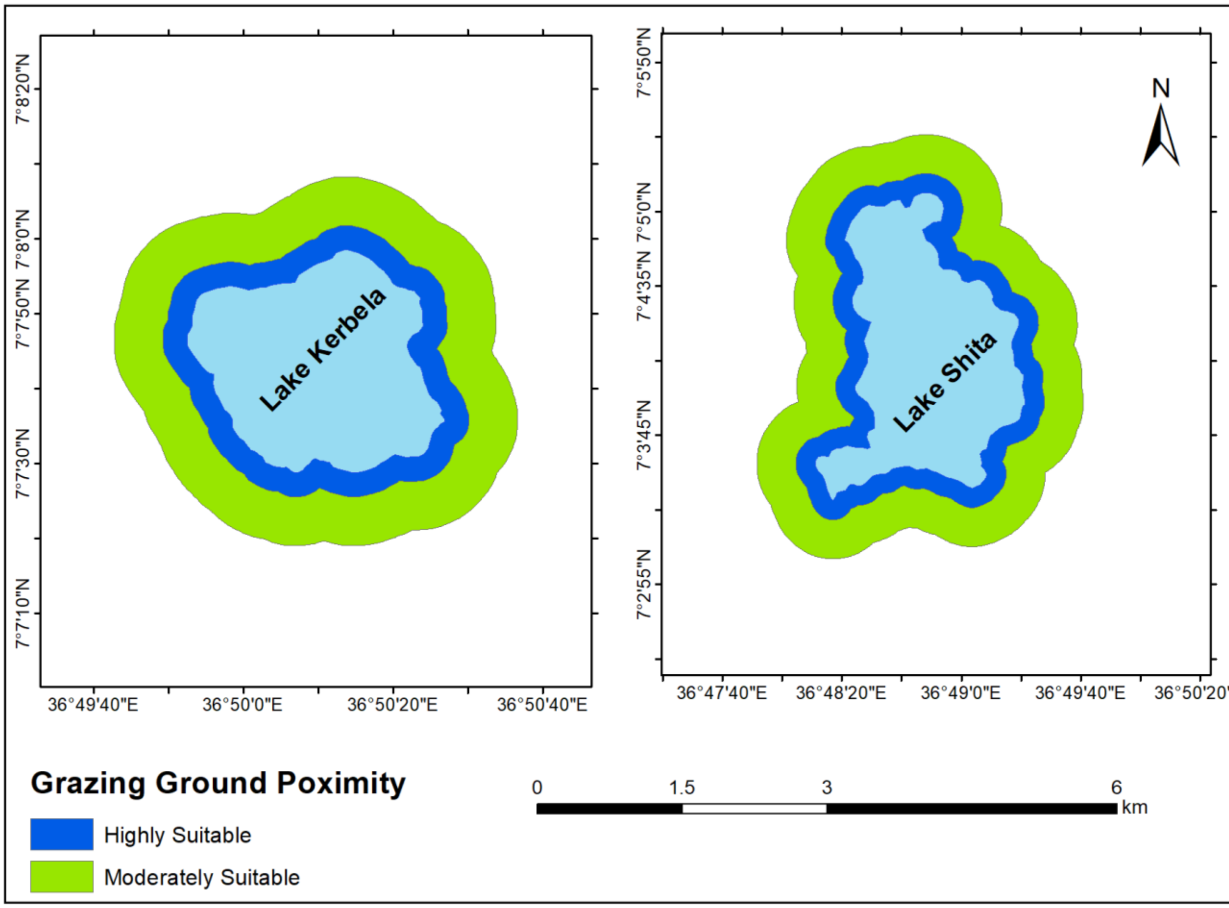


Figure 8. Hippopotamus grazing ground proximity classes to Lake Kerbela and Lake Shita

Hippopotamus could not raise high gradients due to its body size and structure. Hence, the suitable slope values were those that represent conducive travel for the species. Within estimated buffer zone was considered, the suitable area was good but not much. From the Lake shore only 36.97% as highly suitable, 37.2% moderately suitable and the remaining 25.83% is not suitable (the slope classes that could not be climbed by the hippopotamus) (Fig. 9).

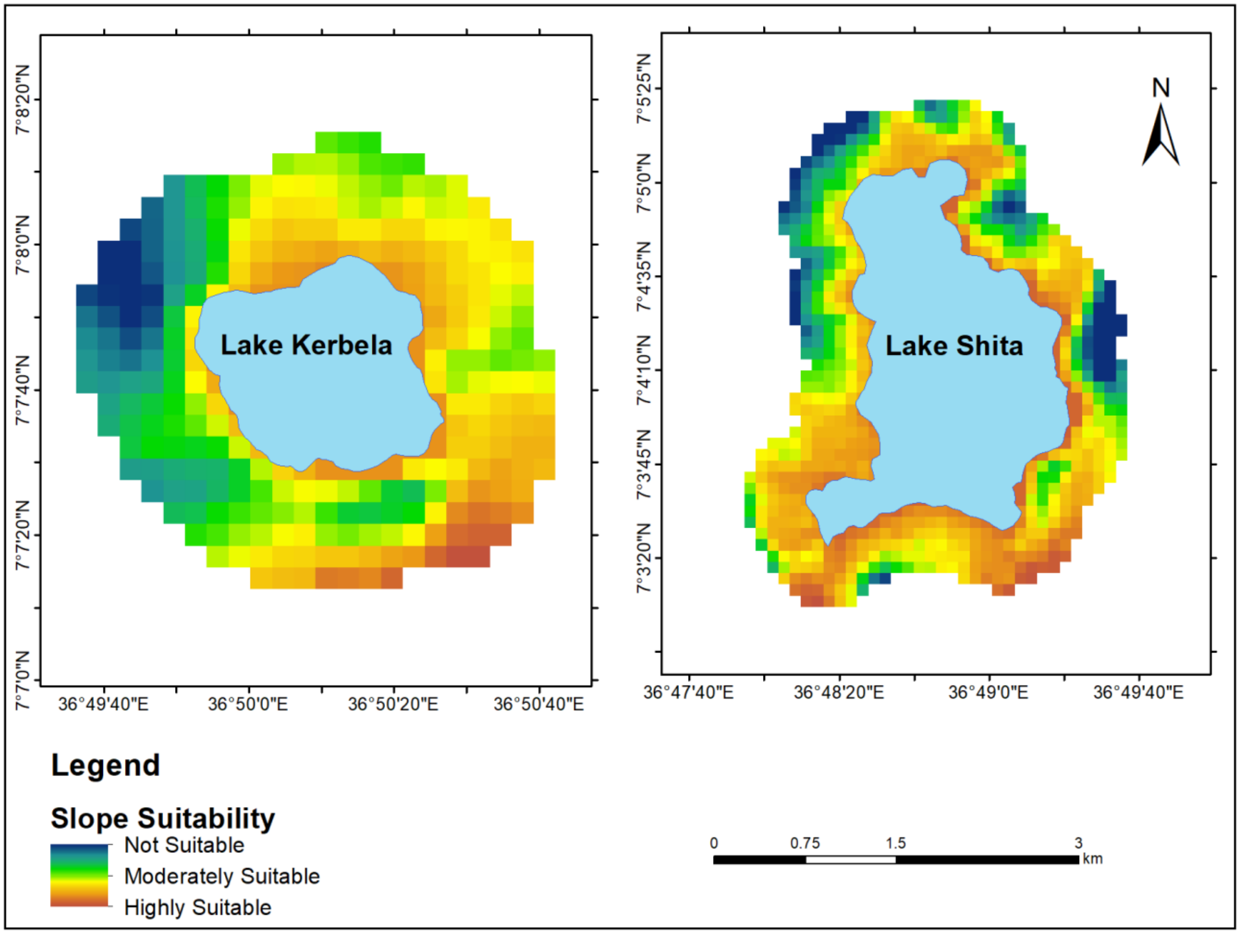


Figure 9. Slope and elevation suitability classes of hippopotamus habitat in the study area

From the estimated buffer habitat of the selected lakes (Kerbela and Shita) only 31.72% of the land area was safe from human interference where as 30.68% of the land was highly disturbed for hippopotamus survival in the study area. On the other hand, 47.29% of the area was moderately disturbed (Fig. 10)

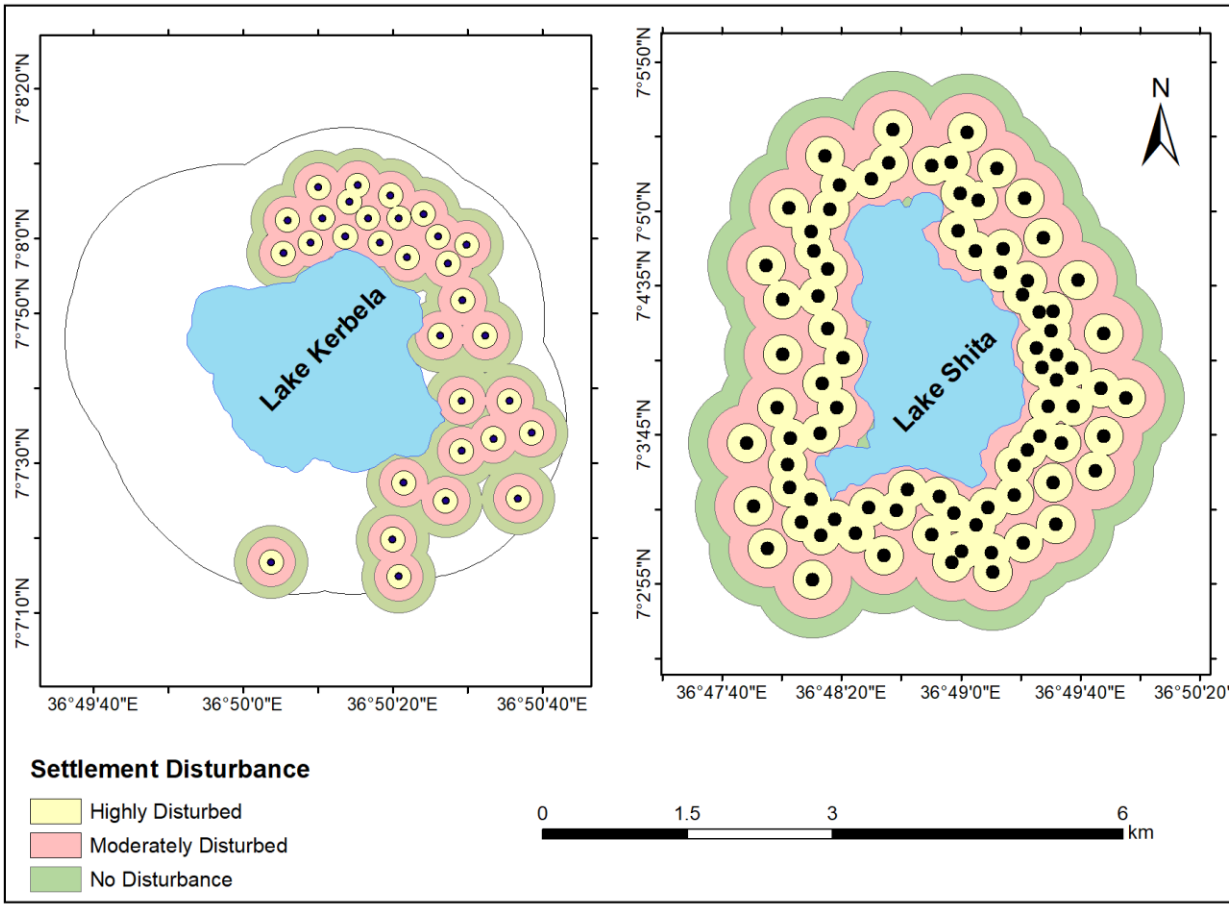


Figure 10. Settlements and livestock disturbance on hippopotamus habitat.

All habitat types (buffer zone) possessed wetland in common and served as foraging sites. They showed high preference for riverine vegetation during the dry season. Out of the total, 54.2% of the hippopotamus utilized riverine habitat during the dry season, only 29.9% used this habitat during the wet season. Grassland with scattered tree habitat was utilized by 37.8% of the hippopotamus during the wet season, and 12.6% during the dry season. Woodland habitat was utilized by 14.2% of the hippopotamus during the wet season, and 16.5% during the dry season. Montane forest was utilized by 18.2% of the hippopotamus during the wet season, and 16.4% during the dry season. During the dry season, most of the the wetland of the open grassland dried up. Other wetlands with forest and woodland provided a better habitat (Table 11). The distribution of hippopotamus in different habitat types during the wet and dry seasons showed significant variation (χ^2 = 17.54, df =3, P<0.05).

Table 11. Habitat association of common hippopotamus in Chebera Churchura National Park during different seasons (RF= Riverine forest, MF=Montane forest, GL=Grassland, WL=Woodland) (Number in bracket show percentages)

Season	Number of Individuals observed in different habitats (%)			
	RF	GL	WL	MF
Wet	148 (29.93)	188 (37.81)	71(14.24)	91(18.28)
Dry	224 (54.22)	51 (12.64)	68 (16.52)	67(16.42)
Mean	186 (42.02)	120 (25.23)	70 (15.33)	80 (17.35)

Hippopotamus utilize the grasssland habitat as feeding site and used the riverine habitat in significant amount in both seasons. This is due to the presence of annual rivers (Shoshima, Zigna and Omo rivers) which provided forgaing plant species year round. The site is very important during the dry season when the grass dried of in other sites. Grassland areas support good number of hippopotamus during the wet season however

4.3. Activity pattern

A total of 7200 behavioural activities (2800) and events (4400) were recorded with in a total of 600 hours behavioural observation. The behavioural activities contributed 39 % and the rest 61% as events. The behavioural activities were carried out during both wet and dry season for 1600 and 1200 behavioural records. From event recods barking (2160) and yawning (2240) behavioural records were carried out during the wet and dry season respectively.

Behavioural activities of hippopotamus in CCNP showed that significantly more time was devoted to resting activities than other activities. The percentages of time spent observed for various activities at different time of the day during wet and dry seasons are given in Figure 11 and 12. Feeding and moving behavioural displays showed two peaks, one in the early morning between 07:00-9:00 h and the other in the late afternoon between 16:00 and 18:00 h. Resting or lying down was highly pronounced during the hottest parts of the day or at noon hours started at 11:30 to 15:30 h. The other activity of hippopotamus was socializing including mating. Mating of hippopotamus takes place in the water. Mating was recorded at a time between 08:00-11:00 h, (41.67%) and between 15:00-17:00 h, (58.33%). Barking and yawning were observed at any time of the day in both dry and wet seasons and mostly increased during the afternoon. Social activites (touching, sexual, biting, rolling, ear flicking and splashing) together represented 5.34% (Figure 12). Activity budget of hippopotamus showed significant vartion across time of the day (ANOVA, P<0.05). However, there were insignfcant varations among activity of feeding (P=0.84), resting (P=0.520), walking (P=0.601), standing (P=0.873) and barking (P=0.605) during the wet and dry seasons. Moreover, yawning (P=0.034) and social activites (P=0.036) showed significant varation between two seasons.

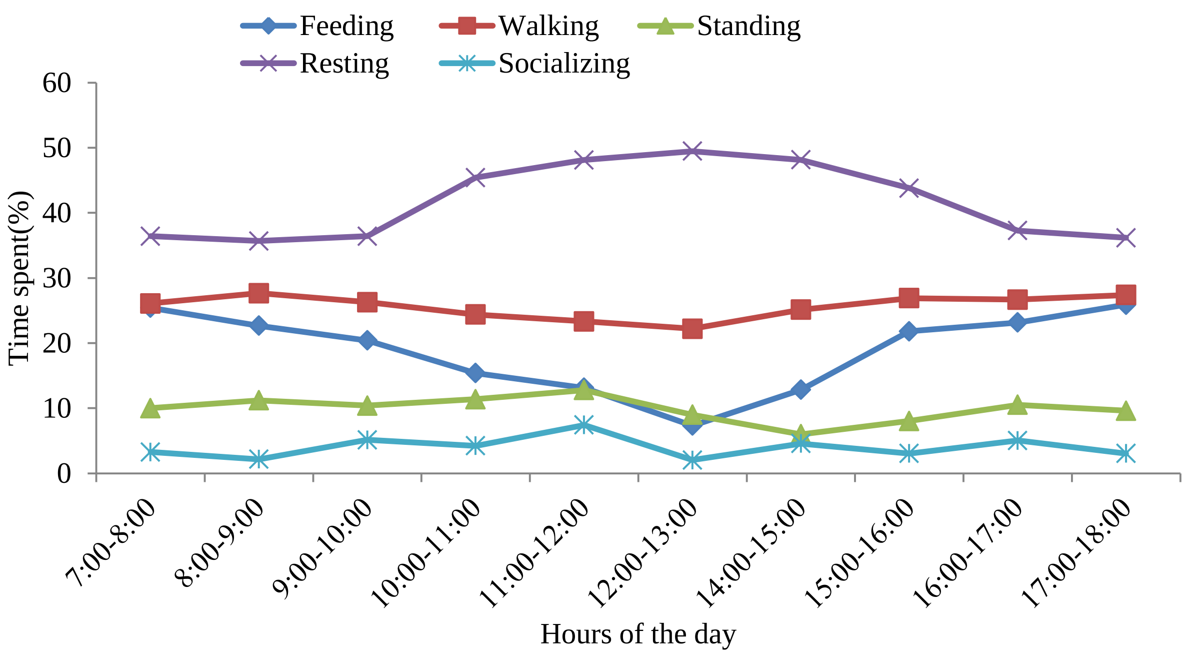


Figure 11. Percentage of time spent in major behavioural activities by hippopotamus in Chebera Churchura National Park during the wet season

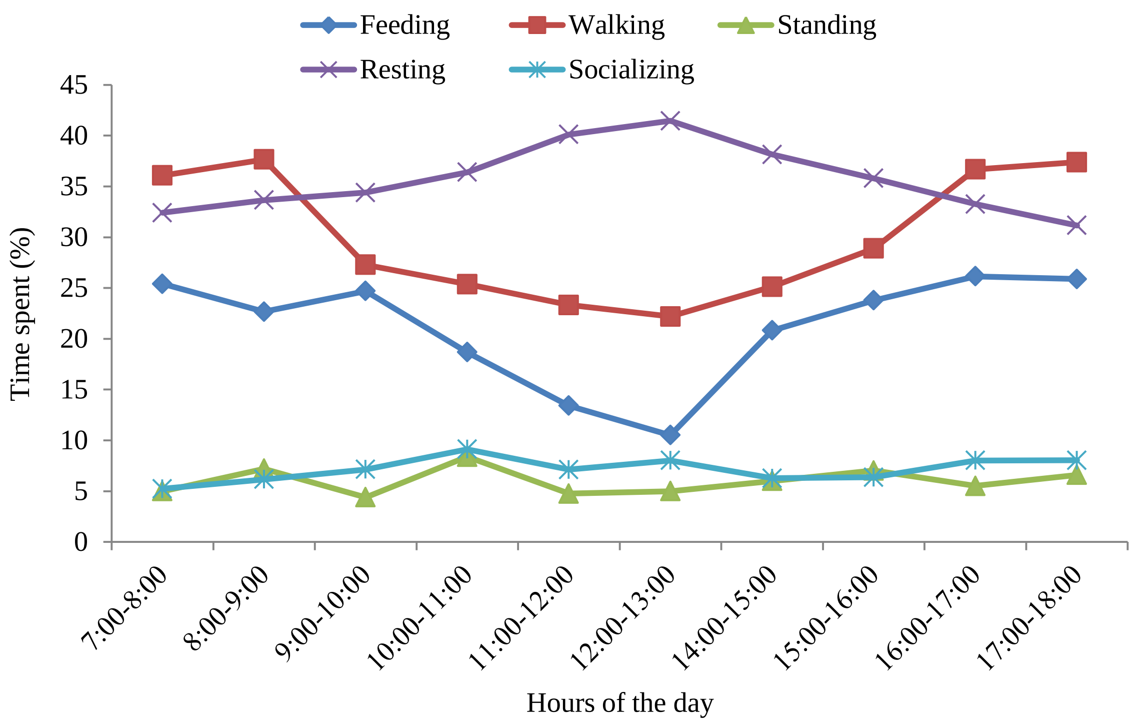


Figure 12. Percentage of time spent in major behavioural activities by hippopotamus in Chebera Churchura National Park during the dry season

Hippopotamus spent feeding (18.75%), walking (25.23%), resting (7.24%), standing (41.59 %) and socializing (4.07%) of their behavioral activities during the wet season. However, during the dry season feeding (21.33%), walking (30.56%), socializing (8.66%) and yawning (48.14%) were greater than the wet season (Fig.13).

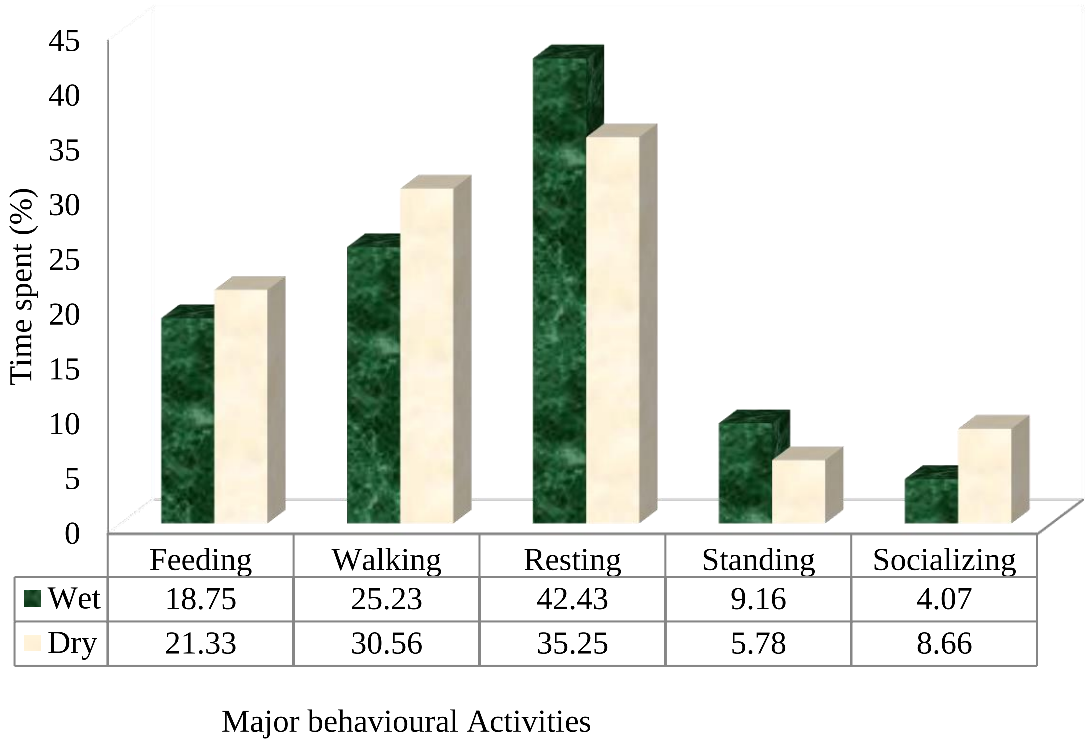
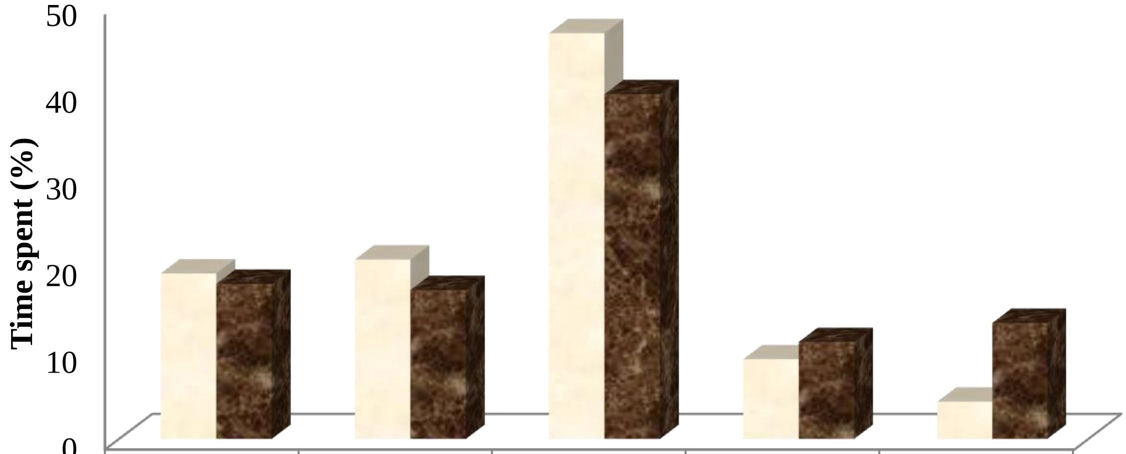


Figure 13. Comparison of behavioural activities of hippopotamus between wet and dry seasons

Adult hippopotamus spent about 46.7% of their day time resting and 9.0% standing with no active leg movements. 19.1% was spent walking and 20.7% feeding making a total time of about 40% moving. Young hippopotamus spent about 39.7% resting, significantly less than adults and 11.2% standing significantly more than adults, making a total of about 51% with no leg movements. Some activity budgets varied significantly between adults and young hippopotamus. Adults spent more time resting and feeding than young ($t_{24} = 3.999$, $p < 0.002$ and $t_{24} = 4.659$, $p < 0.004$), while young spent more time standing ($t_{24} = -2.796$, $p < 0.010$) and socializing ($t_{24} = -7.403$, $p < 0.0001$) than adults. However, there were no significant differences between age groups in time spent walking (Fig. 14).



	Feeding	Walking	Resting	Standing	Socializing
Adult	19.1	20.7	46.7	9.2	4.3
Young	17.9	17.2	39.7	11.2	13.4

Behavioural Activities

Figure 14. Major behavioural activities by adult and young hippopotamus

A total of 48.68% of the daytime activity of the male was spent in resting. Walking was the second prominent activity 34.21% followed by feeding (13.16%). Male hippopotamus spent barking (47.92%) and yawning behavioural events (52.08%). Out of behavioural records of the daytime activity of the female hippopotamus, 25.36%, 34.11%, 37.03% and 3.50% was spent in feeding, walking, resting, and standing, respectively. Females spent more time feeding and than males at (t=4.21, df= 9, P=0.002 and t=4.022, df= 9, P=0.003, respectively). Moving also higher in females insignificantly (t=1.82, df= 9, P=0.103 and t=2.229, df=9, P=0.053, respectively). However, males spent more time resting than females, but have no statistical difference (t=2.16, df= 7, P=0.059) (Fig.15)

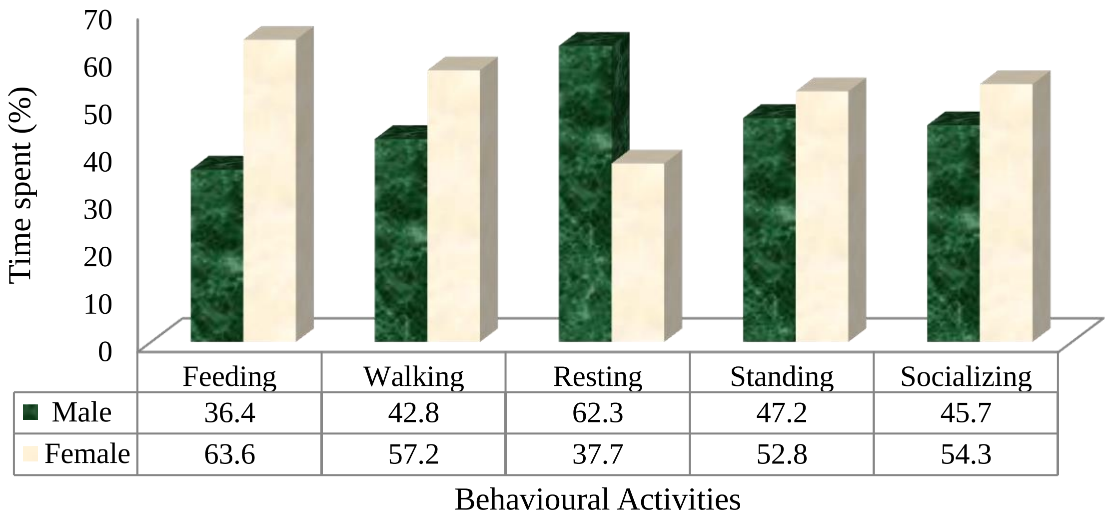


Figure 15. Major behavioural activities by male and female hippopotamus

4.4. Feeding ecology

A total of 40 consumed plant species belonging to 14 families (not including crops) were identified (Table 12). Out of these, 28 species were recorded using feeding signs observation and day time feeding records in focal sample observation, while the remaining 12 species were seen as consumed feeding bites (Plate 8). Family Poaceae contributed the largest (59.28%), proportion of their diet while Polygonaceae (4.72%). Based on the overall percentage contribution, *Eriochloa fatmensis* was the most consumed plant species which accounted for 9.28%. *Typha latifolia* ranked second (8.78%) (Table 12)

Table 12. Plant species eaten by hippopotamus in CCNP

Family	Species	Frequency of observation	Percentage (%)
Amaranthaceae	*Alternanthera nodiflora*	11	0.91
Amaranthaceae	*Alternanthera sessilis*	4	0.33
Apiaceae	*Hydrocotyle mannii*	64	5.30
Apiaceae	*Oenanthe palustris*	9	0.74
Asteraceae	*Aspilia monssambicersis*	12	0.99
Asteraceae	*Guizotia arborescens*	10	1.04
Asteraceae	*Parthenium hysterophorus*	7	0.58
Combertaceae	*Terminalia laxflora*	11	0.91
Commelinaceae	*Commelina benghalensis*	23	1.90
Commelinaceae	*Commelina imberbis*	14	1.16
Cyperaceae	*Cyperus laevigatus*	15	1.24
Fabaceae	*Albizia schimperian*	8	0.66
Cyperaceae	*Cyperus rigidifolius*	69	5.72
Lamiaceae	*Orthosiphon schimperi*	11	0.91
Malvaceae	*Abutilon ceclii*	31	2.57
Menispermaceae	*Stephania abyssinica*	22	1.81
Onagraceae	*Ludwigia erecta*	5	0.41
Onagraceae	*Ludwigia stolonifera*	3	0.24
Poaceae	*Eriochloa fatmensis*	112	9.28
Poaceae	*Echinocloa pyramidalis*	92	7.62
Poaceae	*Cynodon dactylon*	81	6.71
Poaceae	*Echinochloa crus-pavonis*	79	6.55
Poaceae	*Cynodon plectostachyus*	73	6.05
Poaceae	*Leptochloa rupestris*	72	5.97
Poaceae	*Sacciolepis africana*	63	5.22
Poaceae	*Festuca abyssinica*	10	0.82
Poaceae	*Eleusine floccifolia*	9	0.74

Poaceae	*Pennisetum thunbergii*	5	0.41
Poaceae	*Panicum maximum*	24	1.99
Poaceae	*Hyparrhenia cymbaria*	6	0.49
Poaceae	*Arundo donax*	5	0.41
Poaceae	*Panicum* ruspolii	20	1.65
Poaceae	*Panicum repens*	24	1.99
Poaceae	*Sporobolus pyramidais*	30	2.48
Poaceae	*Sporoboius amblei*	10	0.82
Polygonaceae	*Persicaria decipiens*	23	1.90
Polygonaceae	*Persicaria attenuate*	17	1.40
Polygonaceae	*Persicaria glabra*	9	0.74
Polygonaceae	*Persicaria senegalensis*	8	0.66
Typhaceae	*Typha latifolia*	106	8.78
Total		1206	100

Species consumed by hippopotamus are further classified into a group of graminoids which consisted grasses including the family Poaceae and Cyperceae that covered 66.16% of the diet of hippopotamus during both dry and wet seasons (Plate 9). The least ones are shrubs including the family Combertaceae that cover only 1.4% of the diet of hippopotamus.

Herbs in the family of Amaranthaceae, Apiaceae, Asteraceae, Commelinaceae, Fabaceae, Lamiaceae, Malvaceae, Menispermaceae, Onagraceae, Polygonaceae and Typhaceae covered 32.44% of the hippopotamus diet. These are mostly browsed during the wet season and less during the dry season (Plate 10). In CCNP 22 plant species were grazed and browsed intensively (≥1%) by hippopotamus and 10 plant species covered 62 % of the diet of hippopotamus were highly grazed (Table 13).

Table 13. Proportion of seasonal intensive grazed plant species by hippopotamus in CCNP (asterks show intensively grazed species

Foraged species	Dry	Wet	Total	Percentage
Abutilon ceclii	10	21	31	2.57
Commelina benghalensis	–	23	23	1.9
Commelina imberbis	–	13	14	1.16
Cynodon dactylon	39	47	81	6.71*
Cynodon plectostachyus	54	19	73	6.05*
Cyperus laevigatus	10	5	15	1.24
Cyperus rigidifolius	45	24	69	5.72*
Echinochloa crusp avonis	51	28	79	6.55*
Echinocloa pyramidalis	56	36	92	7.62*
Eriochloa fatmensis	63	49	112	9.28*
Guizotia arborescens	–	10	10	1.04
Hydrocotyle mannii	27	37	64	5.3*
Leptochloa rupestris	42	30	72	5.97*
Panicum maximum	13	11	24	1.99
Panicum repens	23	1	24	1.99
Panicum ruspolii	12	8	20	1.65
Persicaria attenuate	–	17	17	1.4
Persicaria decipiens	21	52	73	1.9
Sacciolepis africana	48	15	63	5.22*
Sporobolus pyramidais	30	–	30	2.48
Stephania abyssinica	12	10	22	1.81
Typha latifolia	–	106	106	8.78*

Seasonal availability of 22 foraged species that contributed ≥1% in the diet of hippopotamus either during the wet or dry seasons were shown in figure 15. Forteen forage species were available to the hippopotamus populations, both during the wet and dry seasons. Six species were available only during the wet season. *C. plectostachyus* (6.1%), *E. crusp- avonis* (6.5%), *E.*

fatmensis (9.8%), *E. pyramidalis* (7.6%) and *C. distans* (6.7%), *C. rigidifolius* (5.7%), *H.manni* (5.2%), *L.rupestris* (5.9) were available to hippopotamus during both seasons and together accounted for 66.2% of the available forages. *T. latifolia* was the top foraged species (8.8%) but only available in greatest proportion during the wet season. *C. plectostachyus* was available to hippopotamus more during the dry season (73.9%) than the wet season (26.1%) (χ^2 =11.51, df =1, P < 0.05). Similarly, *E. crusp-avonis* was available to hippopotamus more during the dry (64.5%) season than the wet (35.5%) season. The difference was significant (χ^2=0.48, df =1, P < 0.05). *E. pyramidalis* and *C. rigidifolius* were equally available during the wet and dry seasons. The differences were not significant (χ^2=2.14, df =1, P>0.05; χ^2=1.08, df =1, P>0.05) for the two species, respectively. *C. distans* and *H.manni* were available more during the wet (9.4%) than the dry (1.4%) season and the difference was significant (χ^2=6.37, df =1, P <0.05) (Fig. 14)

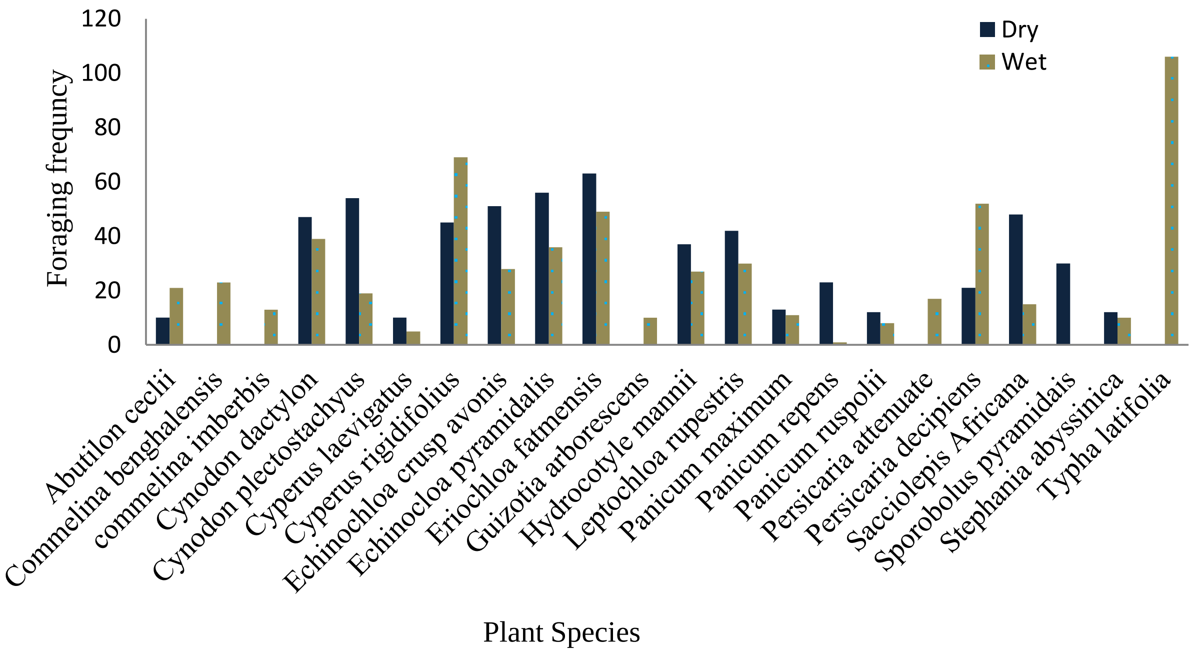


Figure 16. Seasonal foraged species of hippopotamus in CCNP

The plant species foraged by hippopotamus in CCNP signficantlly varied with season. High diversity and percentage of these 22 plant species occurred during the wet season than in the dry one. As shown in figure 21, during the wet season high diversified species were consumed by hippopotamus (α =20.8). However, as the dry season approached most of the species dried off and the diversity of the species decreased radically (α=9.1). The diversity index showed that those species foraged during the dry season were also foraged during the wet season. However, those plant specis foraged during the wet season did not persist during the dry season (Fig. 17)

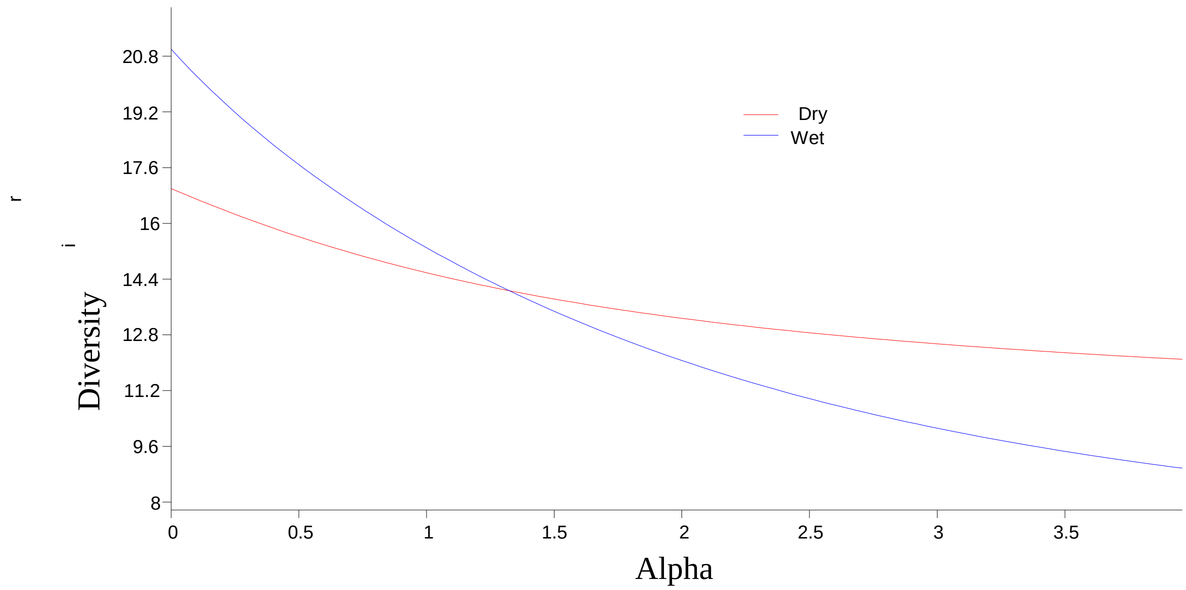


Figure 17. Diversity index of seasonally foraged plant species in CCNP by hippopotamus

Analyses of 80 faecal droppings of hippopotamus showed that the food items such as grasses (graminoids), forbs (herbs), dicots and unknown materials were used in different proportion during wet and dry seasons, respectively (Table 14)

Table 14. Mean percentage of food items identified from faecal analysis of hippopotamus at CCNP (N=80).

	Wet season				Dry season			
Samples	Graminoids	Herbs	Dicots	Unknown	Graminoids	Herbs	Dicots	Unknown
1	54.14	32.45	13.41	---	67.45	14.78	17.77	---
2	51.40	36.26	12.34	---	68.89	2.67	25.5	2.94
3	52.5	30.53	16.97	---	74.32	6.75	18.97	---
4	53.96	27.32	10.27	8.45	76.43	7.89	15.68	---
5	56.32	21.65	22.03	---	65.67	---	21.92	12.41
6	38.5	32.36	29.14	---	58.98	---	24.62	16.4
7	39.5	32.66	14.54	13.3	64.89	6.7	23.52	4.89
8	47.25	28.68	17.67	6.4	67.98	---	21.67	10.35
9	50.64	38.9	10.46	---	54.23	12.78	32.99	---
10	50.28	45.23	4.77	---	63.45	12.67	23.98	---
11	56.24	34.32	---	9.44	54.23	21.56	---	27.21
12	42.38	27.03	---	30.59	65.45	---	---	34.55
13	47.98	21.43	23.43	7.16	65.45	10.56	15.67	8.28
14	53.62	24.56	---	21.82	65.45	13.35	21.2	---
15	39.14	---	45.56	15.3	77.23	---	22.77	---
16	38.42	25.65	3.28	32.65	67.23	9.32	23.45	---
17	55.62	---	27.6	16.78	56.87	---	21.76	21.46
18	65.35	34.65	---	---	56.98	15.67	---	27.35
19	53.09	37.78	9.13	---	64.67	17.89	17.44	---
20	39.62	42.88	8.75	8.75	54.43	14.89	30.68	---
Mean	49.28	28.73	13.90	8.09	64.37	8.37	18.97	8.29

The graminoids found in the faecal droppings of hippopotamus significantly differed between wet and dry seasons (χ^2 = 14.23, df = 1, P < 0.01). During the wet season, more dicots were consumed than the dry season (χ^2 = 24.242, df = 1, P < 0.01). More herbs were also consumed during the wet season than the dry season (χ^2= 16.96, df = 1, P < 0.05). The proportion of food items in the faecal droppings of hippopotamus in CCNP is shown in figure 18

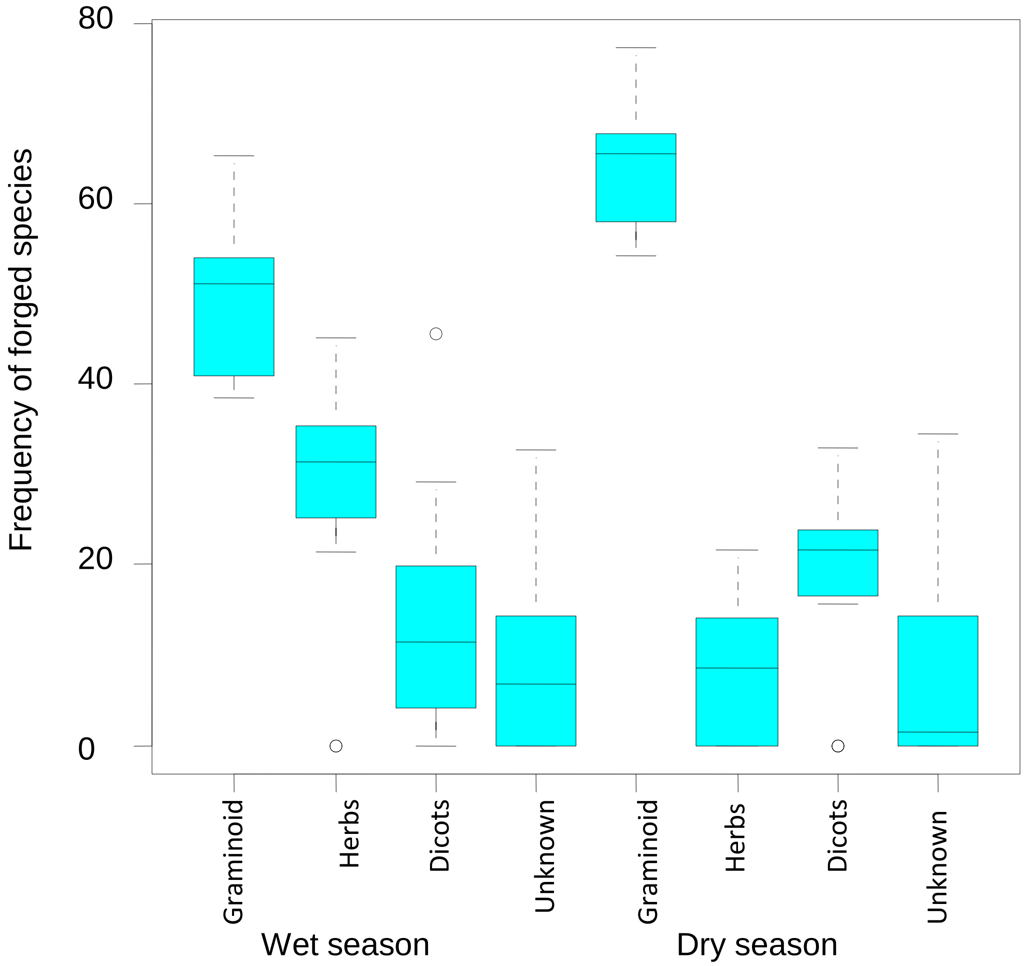


Figure 18. Proportion of food items identified from the analysis of faecal droppings of hippopotamus during wet and dry seasons in CCNP.

The number of foraged species identified by faecal analysis was lower than those identified by feeding observation. Moreover, foraged species that contributed ≥1% in the feeding observation were underestimated in the feacal analysis as they are only classified under graminoids, dicots and herbs. The estimated dietary proportions of browsed and grazed species showed no significante difference between the feeding observation and faecal analysis (χ^2 = 0.26, df= 1, P>0.05). However, the difference in the number of foraged species identified to the species level was significant between the two methods (χ^2=13, df=1, P<0.05). The proportion of foraged species identified by the two methods showed a strong positive correlation (Pearson's Correlation Coefficient, r = 0. 981, P<0.05) between the two methods.

Mean annual cover by ground vegetation varied among habitat types, 44 ± 7.0 % for montane forest and 55 ± 8 % in the grassland (Table 15). Cover by ground vegetation varied between months in all four habitat types ($F_{11, 44}$ = 39.001, p < 0.0001), but did not show significant variation between sites. Annual maximum cover by ground vegetation was recorded for grassland while the minimum cover was recorded for montane forest (12 %) (Table 15).

Table 15. Percentage of ground vegetation cover recorded in CCNP.

Study site	Annual maximum ground cover (%)	Annual minimum ground cover (%)	Mean Annual ground cover (%)
Grassland	86	30	55±8
Woodland	72	21	48±8
Montane	75	12	44±7
Riverine	84	13	48±8

Some species of grasses were present in all the study sites throughout the study period. Maximum vegetation cover was recorded in October 2016 on grassland (73 ± 0.8 %) and the least was in December 2009 on montone habitats (13 ± 1.9 %) (Fig. 19).

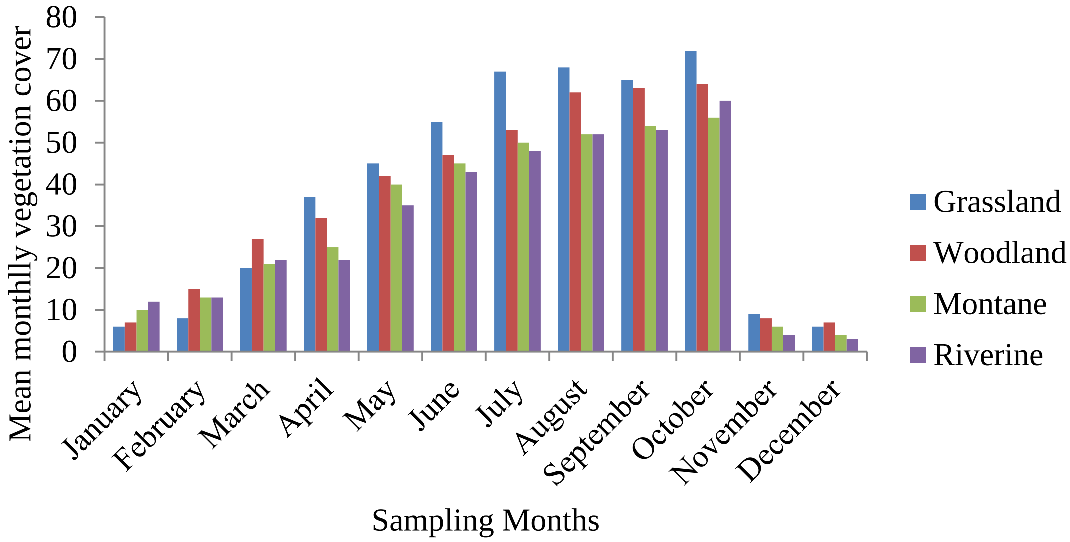


Figure 19. Mean monthly vegetation cover in CCNP

Mean annual sward height ranged from 25 ± 6 cm for montane habitat to 34 ±7 cm or grassland habitat (Table 16). The grassland vegetation was generally tallest in October and September but varied between months ($F_{11\ 44}$ = 22.0, $p < 0.0001$).

Table 16. Annual sward height (%) of ground vegetation recorded in CCNP

Study site	Annual maximum sward height (cm)	Annual minimum sward height (cm)	Mean annual sward height (cm)
Grassland	62	5	34 ± 7
Woodland	54	6	30 ± 6
Montane	46	4	25 ± 6
Riverine	50	3	26 ± 6

The maximum sward height of all sites was recorded for grassland habitat in October 2017 (72 ± 5.9 cm). The shortest sward height was 3.0 cm recorded during December in 2016 and January 2017 in the riverine (Fig. 20)

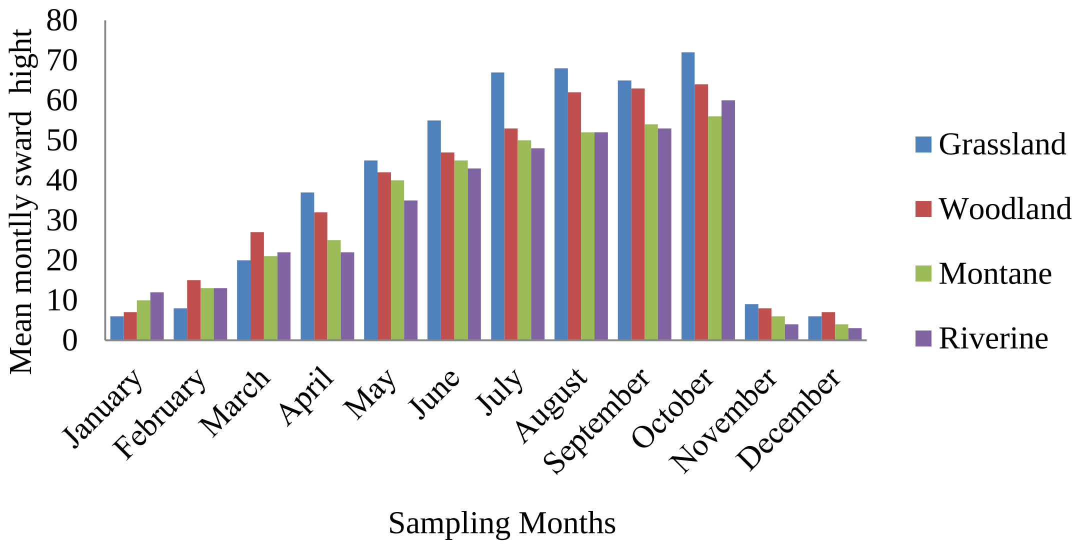


Figure 20. Mean monthly sward height of vegetation in CCNP

The maximum greenness was recorded for grassland and woodland habitat while the minimum was recorded for montane and riverine habitats. Mean annual greenness varied between 46 ± 5 % at grassland to 32± 9 % at woodland. Sward greenness varied significantly between months ($F_{11,\ 44}$ = 86.603, $p < 0.0001$). However, greenness did not vary between sites (Table 17).

Table 17. Annual mean greenness of vegetation in CCNP

Study site	Annual maximum greenness of vegetation (%)	Annual minimum greenness of vegetation (%)	Mean annual greenness of vegetation (%)
Grassland	76	15	46±5
Woodland	68	13	41±9
Montane	53	10	32±9
Riverine	58	12	35±10

Maximum greenness was recorded for montane and grassland habitats in March and April 2016 with 96% greenness while, minimum greenness was recorded for montane habitat in September 2017 (11 ± 2.0 %) and at riverine in August 2017 (11 ± 2.7 %).

The highest mean annual plant mass recorded was 1233 g dry weight m^{-2} for grassland habitat. The lowest was 732 g dry weight m^{-2} for montane habitat. Mean plant mass varied significantly between the four sampling seasons ($F_{3, 19} = 4.3$, $p < 0.02$). However, there were no significant differences in mean plant mass between study sites. Maximum annual plant mass was 2165 g dry weight m^{-2} for Grassland habitat while the minimum annual plant mass was 198 g dry weight m^{-2} for montane habitat (Table 18). Ground vegetation was present in all seasons and in all sampled sites.

Table 18. Annual mean plant biomass recorded

Study site	Annual maximum plant biomass (g dry weight m^2)	Annual minimum plant biomass (g dry weight m^2)
Grassland	2165	301
Woodland	1967	492
Montane	1266	198
Riverine	1684	793

The biomass of standing dry stems did not vary seasonally between study sites. The highest seasonal mean standing dry biomass for Montane habitat (290 g dry weight m^{-2}), while the least was for woodland habitat (54 g dry weight m^{-2}). The ratio of living to dry stems is shown in Table 19.

Table 19. Annual mean biomass and standing dry biomass recorded in CCNP

Study site	Annual mean biomass (g)	Annual mean standing dry biomass (g)	Ratio of biomass to dry biomass (g)
Grassland	757±269	132±44	6:1
Woodland	1126±495	54±33	21:1
Montane	849±171	290±252	3:1
Riverine	1056±247	229±121	5:1

There were inverse correlations between vegetation sward height and hippopotamus density. Increase in hippopotamus density was associated with decrease in sward height (r=-0.53) Greenness and cover also had similar inverse correlations with density of hippopotamus. Therefore, the two had similar effects on the abundance as sward height (Table 20).

Table 20. Summarised correlation between vegetation variables and hippopotamus density in the sampling quadrant of CCNP

	Adults			Juveniles		
Vegetation variable	R-value	n-value	P-value	R-value	n-value	P-value
Vegetation sward height	-0.521	54	0.0001	-0.539	54	0.0001
Vegetation greenness	-0.517	54	0.0001	-0.564	54	0.0001
Vegetation cover	-0.504	54	0.0001	-0.544	54	0.0001

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Human - hippopotamus conflict

Out of the 256 respondents, 179 (70%) were males and 77 (30%) were females. The number of males was significantly higher than that of females (χ^2 = 29.58, df =1, P<0.05). However there was no significant difference in the attitude towards hippopotamus between the sexes. The age of respondents ranged from 15 to 70 years. The majority 182 (71%) of the respondents' age ranged from 35 to 60 years, while 6.3% and 9.4 % of the respondents' were less than 25 and older than 60 years, respectively (Table 21). Young individuals (18-34) showed more positive attitude than the other age groups. Around, 60% of the respondents showed positive attitude and 36% showed negative attitude towards the hippopotamus.

Table 21. Age categories and attitude of the local people in and around CCNP towards hippopotamus

Age category	N	Attitude towards hippopotamus		
		Positive	Negative	Neutral
18-24	16	65.1	25.9	9.0
25-34	36	58.1	34.5	6.8
35-44	66	57.3	35.5	7.2
45-54	72	55.8	37.8	6.4
55-60	42	49.6	41.6	8.8
>60	24	49.1	42.9	8.0
Total/Average	256	55.9	36.4	7.7

Educational level and attitude of the local people are given in Table 22. More than 58% of the interviewed respondents were illiterate. The majority of respondents (55.9%) had a positive attitude towards the conservation area. However, 36.4% had negative attitude. Relatively, better-educated groups (primary and secondary education) had more positive attitude than the non-educated groups. However, this was not significant (χ^2= 6.31, df= 3, P > 0.05).

Table 22. Educational level and attitude of the local community towards hippopotamus

Educational level	N	Percentage	Attitude towards hippopotamus		
			Positive	Negative	No Idea
Illiterate	145	56.6	45.3	49.1	5.6
Primary education	62	24.2	57.8	34.6	7.6
Secondary education	24	9.4	67.4	25.0	7.6
Informal	25	9.8	53.2	36.9	9.9
Total/Average	256	100	55.9	36.4	7.7

Agriculture (crop cultivation and livestock rearing) was the main means of livelihood (76.6%) of the respondents in CCNP, and few (14.7%) depends only on the livestock rearing. About 2.4% of the respondents claimed to have been involved in fishing activity especially in nearby Lake Kerbela and Shita. Moreover, few of them involved in one or secondary occupation and others claim themselves as students and jobless. The majority of respondents (51.1%) had a positive attitude towards the conservation area and hippopotamus (Table 23). Relatively, traders had more positive attitude than other groups.

Table 23. Source of income of the respondent and their view on the hippopotamus

Village	N	Source of Income					
		Agriculture	Livestock	Fishing	Selling things	Jobless	Others
Chebera	40	75.5	15.1	2.1	6.5	0.6	0.2
Serri	30	78.3	14.3	0.0	5.6	0.9	0.9
Yora	60	71.6	18.5	2.5	5.9	0.8	0.5
Shita	28	69.8	16.9	3.9	7.5	0.8	1.1
Menta	32	82.1	11.6	2.3	3.1	0.4	0.5
Churchura	40	73.4	15.5	3.4	4.6	0.6	2.5
Kerbela	26	86.1	8.7	2.4	1.6	0.8	0.4
Total/Average	256	76.6	14.3	2.4	4.9	0.8	0.8

A total of 8 animal species including hippopotamus (six herbivores and two omnivores) were recoded as crop raiders CCNP (Table 24). Among the respondents, 62.2% noted these animals cause a major problem, while 25.9% noted as a minor problem and 11.9% noted as no problem.

This difference was statistically significant (χ^2 = 38.47, df=2, P<0.05). Among these animals, hippopotamus, elephant, buffalo, baboon and warthog were grouped to cause more problems in crop damage. However, wild pig and vervet monkey were not considered as serious pestes in Chebera.

Table 24. Crop raider animals in terms of ranking

Common name	Species name	% of problem ranking		
		Major Problem	Minor Problem	No Problem
African elephant	*Loxodonta African*	68.9	21.4	9.7
Hippopotamus	*Hippopotamus amphibious*	65.6	23.8	10.6
African buffalo	*Syncerus caffer*	75.5	18.4	6.10
Common warthog	*Phacochoerus africanus*	66.3	21.7	12.0
Bush pig	*Potamocherus larvatus*	56.7	30.7	12.6
Porcupine	*Hystrix cristata*	46.7	34.4	18.9
Vervet monkey	*Cercopithecus aethiops*	41.9	39.1	19.0
Anubis baboon	*Papio anubis*	76.2	17.4	6.4
Total/average		62.2	25.9	11.9

Most of the respondents, (91.6%) realize that competition over resources between human and hippopotamus resulting in human-hippopotamus conflict around the Park. 13.3 (5.2%) the respondents noted competition was not a source of conflict between human and hippopotamus in and around CCNP and (3.2%) have no idea on the existence of conflict. Respondents differed significantly (χ^2 = 64.29, df =2, P<0.05) in their suggested views of human-hippopotamus conflict (Table 25)

Table 25. Existence of human – hippopotamus conflict in the study area

Villages	N	Existence of human-hippopotamus conflict (%)		
		Yes	No	No Idea
Chebera	40	92.2	5.2	2.6
Serri	30	84.8	6.6	8.6
Yora	60	88.7	5.3	6.0
Shita	28	96.6	3.4	0.0
Menta	32	89.9	8.5	1.6
Churchura	40	94.1	2.6	2.3
Kerbela	26	95.5	4.5	0.0
Total/Average	256	91.6	5.2	3.2

The threat includes crop loss, overgrazing and human and livestock injury. Most of the respondents (55.9%) noted that crop loss was the major threat whereas, 36.4% of the respondents noted threat to overgrazing and few respondents 7.7% noted threat to human and livestock injuries as shown (Table 26)

Table 26. Major cause of human-hippopotamus conflict

Site	N	% cause of human - hippopotamus conflict		
		Crop raiding	Overgrazing	Human and livestock injury
Chebera	40	65.1	25.9	9.0
Serri	30	58.1	34.5	6.8
Yora	60	57.3	35.5	7.2
Shita	28	55.8	37.8	6.4
Menta	32	49.6	41.6	8.8
Churchura	40	49.1	42.9	8.0
Kerbela	26	45.2	48.1	2.3
Total/Average	256	55.9	36.4	7.7

Distance from the Park and trend in crop damage are presented in Table 27. The respondents noted that in all villages crop damage has increased during the last 5 years by hippopotamus.

Most of the respondents (83.1%) responded as the trend is increasing. The views of the respondents did not differ significantly among this study villages (χ^2 = 0.71, df =6, P>0.05). Only, 8.7% noted the trend is decreasing. More people from Chebera, Kerbela, Menta and Shita faced more crop damage than the other three villages. Relatively, people who live close/near to the Park area and major water bodies faced more problems than those living 3 km away from the Park. Those Kebeles which are far from major lakes and rivers are free from the conflict

Table 27. Approximate distance from the Park and trend of crop damage by hippopotamus

Villages	N	Distance from the Park (km)	Trend of crop damage (%)		
			Increasing	Decreasing	Unknown
Chebera	40	1-2	82.1	9.2	8.7
Serri	30	0-2	84.3	6.6	9.1
Yora	60	0-2	88.7	5.3	6.0
Shita	28	2-5	80.6	8.6	10.8
Menta	32	3-5	79.9	10.5	9.6
Churchura	40	1-3	81.1	8.6	10.3
Kerbela	26	0-2	85.5	8.1	6.4
Total/Average	256		83.1	8.7	8.1

The majority of respondents (78.6%) claim the trend of crop damage increasing in the area over recent 5 years. However, 7.9% of the respondents remarked that crop damage have remained without much change. Only few of the respondents (6.7%) had no idea on the trend of crop damage as shown Table 28. The views of the respondents in the trend crop damage in their locality with in the last 5 years were significantly different (χ^2= 76.11, df=3, P<0.05).

Table 28. Trend of crop damge by hippopotamus since last 5 years

Villages	N	Extent of crop damage			
		Increase	Decrease	No change	No Idea
Chebera	40	78.3	7.2	8.9	5.6
Serri	30	77.2	7.9	8.2	6.4
Yora	60	75.4	9.4	8.4	6.8
Shita	28	78.3	4.3	8.9	8.5
Menta	32	82.1	2.5	7.4	8.0
Churchura	40	76.6	8.2	8.2	7.0
Kerbela	26	83.2	3.1	5.8	7.9
Total/Avera	256	78.7	6.1	7.9	7.2

30.2% of the respondents can identify hippopotamus from the other hazared pests by its large and uniqe footprint in their damged crop area followed by the appearance of the crop damged by hippopotamus. Some can identify with hippopotamus dung during the night time defecated in the cropland as shown in Table 29.

Table 29. Methods of identification of pest animal (hippopotamus) from other problematic animals by the local people in their cropland

Villages	N	Ways of identification of hippopotamus as pest in the cropland area (%)			
		Footprint	See the hippopotamus	hippopotamus dung	Appearance of damaged crop
Chebera	40	28.3	18.2	28.9	25.6
Serri	30	27.2	17.9	29.2	26.4
Yora	60	25.4	16.4	18.4	26.8
Shita	28	28.3	14.3	28.9	28.5
Menta	32	32.1	18.5	23.4	28.0
Churchura	40	36.6	19.2	19.2	27.0
Kerbela	26	33.2	20.1	25.8	27.9
Total/Aver	256	30.2	17.8	24.8	27.2

The result showed that not all crops were equally affected by crop raiders (hippopoptamus). During the present study, 76% of the respondents claimed that maize was the most susceptible crop to hippopotamus, followed by Enset (60), Teff (55%), Banana (50%), sorghum (40%) and potato (36%). Whereas, 21% of the respondents reported that wheat was the least susceptible crop to be damaged by hippopotamus (Table 30)

Table 30. Types of crops grown and damaged by hippopotamus in and around CCNP

Site	N	Types of crop damaged by hippopotamus (%)						
		Maize	Enset	Teff	Banana	Sorghum	Potato	Wheat
Chebera	40	76.4	56.3	55.2	46.4	42.2	36.7	23.8
Serri	30	66.2	57.5	57.8	45.8	38.4	32.6	27.5
Yora	60	78.3	64.5	62.4	48.3	45.6	40.4	20.6
Shita	28	82.8	66.8	48.9	58.4	44.8	32.8	26.3
Menta	32	72.4	54.3	52.1	50.3	34.6	30.6	20.3
Churchura	40	74.6	58.3	54.2	52.5	40.5	37.4	16.5
Kerbela	26	88.5	62,7	63.9	56.3	47,5	34.6	21.2
Total/Average	256	76.5	59.5	56.3	51.1	41.9	34.9	22.3

In Chebera Churchura National Park, hippopotamuses were observed and reported to cause damage on seven cultivated crops at different stage of growth and mode of damage. Feeding and trampling were the two common modes of crop damage recorded by hippopotamus. Except potato and Banana, which were damaged by trampling, the other crops were damaged both by feeding and trampling. Hippopotamuses were reported to damage crops mainly during the night time, which was severe once they invade crop field and they preferred mature and intermediate stages of the crop. In CCNP, maize was the most preferred crop by hippopotamus and was intesively damaged; while wheat was the least preferred crop (Table 31).

Table 31. Mode of crop damge, stage and preference by hippopotamus (Seedlings (1.5 feet from ground or less), Intermediate (2–3 feet from ground), Mature (taller than 3 feet)

Type of crop	Mode of damage	Seedlings	Intermediate	Mature	Preference
Maize	Feeding and Trampling	No	✓	✓	1st
Enset	Feeding and Trampling	No	✓	✓	2nd
Teff	Feeding and Trampling	No	✓	✓	3rd
Banana	Trampling	✓	✓	✓	4th
Sorghum	Feeding and Trampling	No	✓	✓	5th
Potato	Trampling	✓	✓	No	6th
Wheat	Feeding and Trampling	No	✓	✓	7th

In the study area, the amount of crop damage (kg) and cost estimation (birr) were calculated from the direct observation in the five gird laid in different sites of CCNP as shown in Table 32. A total mean of 137 kg per household with a mean total cost estmation 1883 Ethiopian birr ($70) (the exchange rate were 27 birr) were lost due to hippopotamus.

Table 32. Annual cost of crop losss due to crop-raiding by hippopotamus in CCNP

Type of crop	Loss of crop in (kg/household)	Cost estimation (in Birr/household)	Cost estimation (in Dollar ($) /household)	Rank of damage
Maize	450	5625	209	1st
Enset	267	2670	99	2nd
Teff	79	1975	73	3rd
Banana	67	1750	65	4th
Sorghum	45	645	24	5th
Potato	37	370	14	6th
Wheat	15	150	6	7th
Average	137	1883	70	

Frequency of crop raiding by hippopotamus is shown in Table 33. Most of the respondents (43.6%) claims about the frequency of crop raiding by hippopotamus as three times and (22.5%) respond more than three times. However, (21.3%) responded hippopotamus visit their crop land twice annually and few respondents (12.5%) recall as once. However it was insignificant among the studied respondents on the occurrence of crop riading ($\chi^2 = 20.71$, df =3, P>0.05)

Table 33. Frequency of crop raiding (weekly) by hippopotamus during the croping month

Frequency of Conflict occurrences	Frequency	Percentage
Once	32	12.6
Twice	55	21.3
Three times	111	43.6
More than three times	58	22.5
Total	256	100

Hours of the day in which crop raiding by hippopotamus occurred is shown in Table 34. From total respondents, the majorty (65.9%) responded that crop damage by hippopotamus occur at night, while (10.5%) noted as it occured in the early morning and few of them (7.9%) respond as in the afternoon and other were unsure of the time when the damge occurred and no specific time for the damge.

Table 34. Hours of the day in which crop raiding by hippopotamus occur

Hours of day in which Conflict occur	Frequency	Percentage
Morning	27	10.5
Afternoon	20	7.9
Evening	31	12.3
Night	169	65.9
No specific time	6	2.3
Unsure	3	1.1
Total	256	100

It was recorded that the season of crop damage varied with the cropping practices, but most of the crop raiding occurred during the wet season. Agricultural crops, especially maize, sorghum, banana and enset comprised a major portion of the diet in the CCNP boundary area. These were the crops most cultivated by the farmers and therefore more abundant and accessible to hippopotamus. Focus group discussion indicated that most of the damages occurred at night from June to October. In few cases, crop raiding occurred during the day (morning and afternoon) and at any time. Chebera, Serri, Kerebla and Menta villagers were the most affected by hippopotamus as they are near the major lakes and rivers.

Local communities use different techniques to control (minimize) the problems caused by hippopotamus on cropland at night. Most respondents reported guarding as an effective method in all villages (61.6%), followed by fire and smoking (23.1%), physical barriers (thorn fences) (10.1%) and narrow and deep furrow (5.2%) (Table 35). Views of respondents among villages did not significantly differ (χ^2 = 48.82, df = 6, P>0.05) in using the different techniques for protection of crops and livestock. No one used only one method alone, but combined and integrated all the local methods to prevent crop raiding by hippopotamus.

Table 35. Different techniques to control (minimize) the problems caused by hippopotamus on cropland at night

Villages	N	Deterrent Techniques			
		Guarding	Fire smoking	Thorn fences	Narrow &deep furrow
Chebera	40	68.3	22.2	8.9	5.6
Serri	30	57.2	23.9	8.2	6.4
Yora	60	55.4	23.4	8.4	6.8
Shita	28	58.3	21.3	8.9	8.5
Menta	32	62.1	22.5	7.4	8.0
Churchura	40	66.6	25.2	8.2	7.0
Kerbela	26	63.2	23.1	5.8	7.9
Total/Average	256	61.6	23.1	10.1	5.2

The local people in the study area proposed different methods to minimize crop damage by hippopotamus. Among the respondents 71.3% suggested compensation from the government for the crops damaged. 12.4% of the respondents wanted to minimize the number of problem animals. Other (9.2%) respondents suggested the use of different traditional techniques to minimize the damage caused by hippopotamus. Only (2.5%) of the respondents suggested killing problem animals around them. Few of them (2%) proposed to displace problem animals to other areas. Among the respondents, 2.8% did not respond about the techniques (Table 36). Respondents differed significantly (χ^2 = 74.29, df=4, P<0.05) in their suggested views to reduce crop damage by hippopotamus.

Table 36. Different methods proposed by the local people to minimize crop damage by hippopotamus

Activity	Frequency	Percentage
Using traditional method	7	2.8
Trap and move them	14	5.3
Shoot them	12	4.5
Compensation	218	85.5
No idea	5	1.9
Total	256	100

All respondents are aware of the serious crop damage by large mammals including hippopotamus by directly feeding on crops, trampling and footing of the farmland. As most members of the community members are farmers, and the crop damage affects their survival. As a result, they develop a negative attitude towards crop raiding animals. Before the establishment of the Park in 2006, the community minmize the damage by killing problematic animals which they are not allowed to practice now. The community seemed to be disappointed about the crop loss by large mammals. Discussants also stated that the Park has restricted access to resources. Some discussants, however, recognized the value of the Park and the wildlife for the contribution to the regional economy through tourism and climate stability.

5. DISCUSSION

5.1. Population size and structure

Hippopotamus population estimate in CCNP showed differences during wet and dry seasons. The wet season census showed high hippopotamus population estimate compared to the dry season estimates. This was primarily due to the better quality of fodder available during the wet season in the study area. The availability of lush growing grasses and herbs during the rainy season provides better fodder in the grassland habitats. Moderate temperature and cloudy weather conditions appeared to cause the animals to be more active than during the dry season (Chomba, 2013). Usually rainfall facilitates vegetation growth and provides suitable conditions for the survival of the species.

More young animals (juvenile) were also observed during this season. Even though breeding in hippopotamus is not strictly seasonal as noted by Estes (1992) most conceptions occur during the dry season and birth peaks during the wet season which may explain the results of the present study showing increased population of hippopotamus during the wet season. Various stresses in connection with habitat destruction, poaching, predation and diseases as noted by Sinclair (1977), Sutmoller *et al*. (2000) and Jolles (2004) in the African continent might also have similar effects on the hippopotamus population in CCNP.

There was high proportion of females in the population, indicating that the hippopotamuses have a potential to increase their number. However, only low proportion of young to that of other aged groups was observed during the present investigation. Mortality during the first year of life is high in the hippopotamus as the calves become susceptible to predators such as lion, hyeana, crocodiles and diseases (de Vos *et al*., 2001; Vissher *et al*., 2004). In CCNP, the young individuals especially in the river are affected by floods as a result the rate of mortality is high.

The reproductive behaviour of hippopotamus affects the counting of young individual becouse after the birth, females separate calves from the group before returning to the water with the calf, but after 10-14 days, the female and her offspring rejoins the herd (Post, 2000; Martin, 2005; Blowers, 2008). The estimated density of 30.2 hippopotamus/km of river and lakes in CCNP is higher than the 20.2 hippos/km reported for Liwonde National Park in Malawi in 1993

(Bhima, 1996) and 21.6 hippo/km reported for Luangwa River in Zambia in 1970 (Marshall and Sayer, 1976).

However, direct comparisons with estimates of hippopotamus densities in other water bodies are often complicated by differences in habitat suitability (Olivier and Laurie 1974; Eltringham 1999). This shows that the population of hippopotamus is relatively in a good status. According to Okello, *et al*. (2005), hippopotamuses are hunted extensively for their meat value, superior quality of tusk and hide. However, in CCNP, the local people do not hunt hippopotamus for their meat and tusk. This is because culturally the people in the area do not have a trend to prepare tusk for markets. However, they rarely hunt hippopotamus for hide and appreciate the strength and durability of the hide. In addition because of hippopotamus damage to plantation and other crops nearby the Park, the farmers near the Park hunt and shoot hippopotamus as aresult of crop damage.

The similarities in expected group sizes across regions complicate identification of high-quality hippopotamus habitat. Nonetheless, the relatively large group sizes in the lakes and rivers may indicate overcrowding because the size of crater lakes are small in size as noted by Olivier and Laurie (1974); Klingel (1991) and Viljoen (1995).

Although the count was carried out during the dry season when most temporary water bodies dried out in the CCNP and the distribution of hippopotamus is restricted, the counts suggested that the major permanent river and the five crater lakes mentioned above offer more favourable water conditions for hippopotamus during the dry season compared to its tributaries. However, land-use changes and livestock herding may be adversely affecting hippopotamus in the section of the Shoshima and Zigna River within the pastoral ranches and its tributaries where hippopotamus form relatively large groups. The spatial distribution on the lake is not uniform as the southeastern shores had more hippopotamus compared to the other side of lake. The western coast of the lake had very few hippopotamus, with only a few in the extreme north and south where there is less human settlement. Tikurewuha River has almost no hippopotamus compared to the other major rivers. The density of hippopotamus is higher along the Zigna River (19.1 hippos.km-1) than other areas.

The ratio of calves to adults represents the apparent juvenile recruitment rate, although not all calves and adults are likely to be counted in any census and some sub-adults grouped with adults may not have reached breeding age. However, a high calf : adult ratio is not necessarily indicative of a fast growing population because the actual rate of population growth is not only a function of this ratio but also of juvenile and sub-adult recruitment and mortalities, thus poor possibility of sighting hippopotamuses and yielding higher counts does not indicate a true population increase. The density of hippopotamus in Chebera Churchura National Park is similar to the Masai Mara National Reserve in 2006 which shows a stable population. Our results, however, indicated that the CCNP hippopotamus population is stable against the background of deteriorating habitat conditions related to habitate loss, conflict with human and progressive habitat desiccation (Ogutu *et al*. 2007), and fundamental land-use changes (Homewood *et al*. 2001; Serneels *et al*. 2001a; Lamprey and Reid 2004; Mutie *et al*. 2005; Ogutu *et al*. 2009). Even though there is no written document which shows the trend of hippopotamus population in the study area before this census, local respondents indicated that the population of hippopotamus had an increasing trend in the present study area. Their estimation was 245 heads in 2006; however, in the present study the count was almost double. Population size increases of other dominant herbivores were also observed in the present study area. This might be related to the better management activities currently being implemented and the good habitat quality maintained due to reduced anthropogenic disturbances in the Park. Chebera Churchura National Park is at present a National Park, but, during 2006, it was a controlled hunting area. Therefore, there was less effective management activity in the area. Park staff and scouts were employed for effective and regular patrolling of the Park after the establishment of the area as a National Park. Anthropogenic factors that have impacts on the quality and quantity of the Park ecosystem were reduced due to better conservation efforts. This might have helped to increase the population of hippopotamus and other wildlife in the present study which agree with the finding of Abrham Megaze *et al*. (2017). Local respondents also indicated that human intervention was intense before the establishment of the National Park and the area experienced serious environmental problems as a result of deforestation, overgrazing, encroachment and illegal hunting. According to Halley *et al*. (2002), local wildlife migration may occur because of a change in forage quality and quantity, water availability and landscape features such as vegetation composition and structure. Movement strategies allow species to find new resources, escape predation pressure, find new mates and improve their reproductive potential (Scheibe *et al*., 2009). In the present study, there was seasonal habitat use movement to fulfill their nutritional need but, no migration was recorded in the study area.

The knowledge of sex ratio and age composition among the mammal populations is crucial for evaluating the status of the population as these variables reflect the structure and the dynamics of populations (Wilson *et al*., 1996). Even if an equal sex ratio of animals at birth is assumed, there is an increased mortality in young male ungulates (Ndhlovu and Balakrishnan, 1991). A balanced age structure must be maintained in any animal population for optimal productivity, because deviation from such an age structure could adversely affect the population growth rate. Yet, the ratio of the age classes in a population can be an indication of its current and expected reproductive status (Bothma, 2002).

In Chebera Churchura National Park, the age ratio of hippopotamus population was skewed towards adult populations. One possible reason for the low proportion of young hippopotamus in the study area might be due to the presence of predators, such as lion, crocodile, and hyaena or it would be the population reaching at its saturation point. The female-biased population of hippopotamus in CCNP may indicate that this population has potential to increase. Hippopotamus give birth to a single calf. Most calves are fully weaned by 12 months of age (Sayer and Rakha, 1974) and death rate during the first year of birth is high as calves become susceptible to predators, disease and flood. However, the present study shows better young to adult ratio 5.8:100 compared to Luangwa River in Zambia in 1983 which were 4.8: 100. This is less than the ratio reported for the Mara hippopotamus of 9:100 (Tembo, 1987).

The sex ratio of male to female was not equal. A female-biased sex ratio showed that the species has healthy, increasing trend in the study area as revealed earlier by Tsi *et al*. (2011) in the Faro National Park, Cameron. The plausible explanation for the variation in the sex composition may be basically due to the high mortality of males because of aggressive interactions with other males to get access to the best resources as well as fights between bachelor males and territorial males for mating (Zubkowicz, 2005; Blowers, 2008). Reproductive fights may lead to the death of weaker males, but stronger males can defend their positions for many years until they get a rival. Fights for the possession of a territory can be fierce and the animals may inflict considerable damage on each other with their huge canines and cause of death. Territorial males do not normally fight each other and severe fights usually occur only when a bachelor challenges a territorial male for control of the territory. Females have been observed to live in groups, but males were mostly found in solitary areas (Chomba, 2013).. In CCNP, hippopotamuses were observed in smaller herds during the wet season and in larger herds during the dry season. Seasonality in behavior in relation to herd size and bonding may differ within species, sexes, age groups and individuals (Lehner, 1996). In the Mara River in the Serengeti, studies have shown that groups tend to split more often during the wet than the dry seasons (Olivier and Laurie, 1974). This may be due to food availability but mainly due to water resource availability because group size decreased after a rise in water levels.

Hippopotamuses live in close association with rivers, streams and lakes (Graham *et al*., 2002; Dunstone and Gorman, 2007; Dunham *et al*., 2010). These places are used as suitable and safe resting places mainly during the day time. Alterations to their environment affect them differently in different sites. In CCNP reactions to the changing conditions in sheltering or resting and feeding grounds are likely to be manifested through their behaviour and aggregation or varying the herd size in responds to their daily activities. During the day time, they aggregate in the resting site with large herd size while in the night time they spread for foraging activities and form small herd size as noted by Chomba (2013). There are no social bonds between the adults within a group despite the fact that hippopotamus lie in close contact with each other. The social bonds are between the mothers and daughters (Blowers *et al*., 2008). Males form separate bachelor groups.

During the dry season, in CCNP, grasses dry out. Fires were common and most of the rivers and streams were dry out. It was observed that hippopotamus in CCNP generally avoid both grasslands and woodlands that had been burned. They only move into to the riverine forest. Therefore, at this time, hippopotamus disperse and form smaller groups for intensive foraging of the available resources at night while during the day time; they aggregate to large rivers and lakes unlike the wet season. This might help them to get dispersed forage in all available habitats including those of marginal areas. By living in small herds, during the night, they might get access to addational resources that are too sparse for large herds. These strategies of hippopotamus may alleviate malnutrition problems during the dry season (Sinclair, 1977; Ryan and Jordaan, 2005; Venter and Watson, 2008; Tshabalala *et al*., 2009). Adult male hippopotamus leave the herd and form their groups during the dry season. They return to the herd during the wet season. Prins (1996) noted that movements of adult bulls into and out of mixed herds were clearly related to changes in physical condition. Old males remain permanently separated from the large breeding herds and form their own bachelor herds of 3–4 individuals, as indicated by Macandza *et al.* (2004) and Venter and Watson (2008). The present observation showed that herds of 2–4 old males during the dry season always forage in small patches of green grass, on the banks of rivers, and at the edges of the springs and swamps in CCNP. Unlike pigmy hippopotamus which is solitary in the forest, adult male common hippopotamuses were consistently observed with the same herd throughout the year (Korte, 2008). Lewison and Carter (2004) reported that hippopotamuses were congregated in larger herds of 51–70 individuals. The average herd size in the Mara River reached 100 individuals (Sinclair, 1977). But, in the present study area, the herd size of hippopotamus was small. This smaller herd size in the CCNP may be related to the size of lakes and rivers as well as patchiness and quantity of food resources on the landscape. The pattern of herd size in different habitat types of the study area was different. During the wet season, hippopotamus formed larger aggregations in the grassland with scattered trees than in the forest and riverine habitats. This might be due to the abundance of food sources in the grassland habitat compared to the dry season. Individuals of hippopotamus distributed themselves in a more aggregated spatial pattern when resting in clearings than in the forest habitat (Melletti *et al*., 2008, 2010). Korte (2008) also reported that hippopotamus depend on open habitat adjacent to continuous forest for resting. In CCNP, late dry season is the most critical time for the hippopotamus. During this season, hippopotamus move into riverine vegetation to get a better foraging area. This is probably related to the habitat complexity and stability compared to other habitat types. Even though the habitat is of high quality, it may not be able to support large herds of such large mammal populations. Hence, it becomes essential for them to be in smaller herds, as small herds can utilize scattered resources more efficiently than large herds.

5.2. Distribution and habitat association

A central focus in animal ecology is to consider the association of an animal with its environments, particularly the varieties of habitats that it occupies or prefers. Habitat selection by animals reflects a strategy that enhances survivorship and successful reproduction (Western, 1975; Funston *et al*., 1994; Bennitt *et al*., 2014). For an organism to reproduce and maintain a viable population, the basic needs (food, cover, space and water) must be available in the appropriate quantity and quality (Fulbright and Ortega, 2006). One of the prerequisites for habitat management is therefore to identify limiting factors and optimum levels for food, cover, space and water (Johnson, 1980). The types and availability of these requirements are likely to have some impacts on the hippopotamus behaviour, abundance and movements on temporal and spatial scales.

All habitat types do not possess balanced resources and equally used by ungulates throughout the year (Graham *et al*., 2002). Consequently, habitat utilization by ungulates varies on seasonal and circadian basis (Demarchi and Bunnell, 1995; Dussault *et al*., 2004) and governed by tradeoffs between associated costs and benefits (Rettie and Messier, 2000). To optimize the cost and benefits, ungulates use different habitats at different periods.

Availability of water, particularly during the dry season is one of the major pre-requisite for occupation of a site by hippopotamus (Graham *et al*., 2002; Dunstone and Gorman, 2007; Jablonski, 2004). Nearby foraging grounds is another major requirement (Viljoen and Biggs, 1998; Eltringham, 1999; Harrison *et al*., 2007). Apart from stagnanat waters, sites with slow moving waters such as river bends, river confluence and lagoons increase the suitability of the sites for hippopotamus (Chansa and Milanzi, 2011). Areas of slow and relatively shallow, gently sloping banks are favoured as it enables hippopotamus to lie half immersed while resting (Laws and Clough, 1966; Field, 1970, Olivier and Laurie, 1976; Viljoen and Biggs, 1998). Spatial variations among hippopotamus in other areas in Africa have been high like in the Kruger National Park (Viljoen and Biggs, 1998) and in Zambia (Wilbroad and Milanzi, 2010). In CCNP, forage and water availability are important influencing the distribution and behaviour of hippopotamus (Sinclar, 1977; Prins, 1996).

Even though, in the study area, hippopotamus use lakes and rivers as a resting site, they do not show much fluctuation as the water level and rainfall is more or less stable. But, they are highly affected by foraging site especially during the dry season as grasses dry out. This leads, to seasonal movement of hippopotamus in the area where abundance of green forage in different habitat types is avaliable. Comparison of the seasonal changes in habitat association shows the hippopotamuses have high preference for riverine vegetation during the dry season and grassland vegetation during the wet season. During the wet season, hippopotamuses were observed in grasslands with scattered trees. The association of hippopotamus with the riverine vegetation increased significantly during the end of the rainy season. Shift in hippopotamus abundance and distribution was reported by Harrison *et al*. (2007) in Shire River in Malawi. Hippopotamuses moved into temporary water sources as the wet season advanced. Although the river was perennial, this led to seasonal variations in abundance. Similarly, such seasonal patterns were also reported in Queen Elizabeth National Park in Uganda (Field and Laws, 1970, Lock, 1972).

The riverine vegetation is high in species richness (Redfern *et al*., 2003). The Meka riverine vegetation located in the northern part of the CCNP is a narrow strip, with permanent water resources (Shosima, Zigna and Tikurewuha) and a hot spring, which supports an exceptionally high density of hippopotamus and other large mammals such as African elephants and African buffalo as was reported by Abreham megaze (2015). It was observed that African elephants and Hippopotamuses are important in checking the growth of bushes and to promote grass regeneration, thereby creating conducive habitat for other large wildlife in this habitat. But, patches that were used by hippopotamus during the dry season were also grazed by elephants and other grazers. Grazing by these competitors may reduce the amount of food for hippopotamus. The dependence of local people on Park resources for their livelihood was very high in this habitat. The Hora hot spring, which is located around the riverine vegetation, has a large influence on the seasonal movement of people and livestock in the Park, and the sustainability of the practice has been questioned and remains a central issue for conservation of wildlife in the area. Similar result was reported by Western (1975), Verlinden (1997), de Leeuw *et al*.(2001), Redfern *et al*. 2003 and Ogutu *et al*. (2010) human activities and location of water sources influence ecosystem structure and function, in particular the spatial and temporal distribution of wild herbivores and livestock.

In CCNP Behea, Chofrea, Koka, Zigna and Shosima site were the most suitable for Hippopotamus among the nine hippopotamus sites. This is because they provided water and forage throughout the year and thus hippopotamus abundance was maintained as noted by Eltringham (1999). Hippopotamuses are influenced by habitat choice and nature of the foreshore or the bed of lakes and rivers, as well as by the depth and flow of the water. Most groups of hippopotamuses are found where there are relatively firm and gently sloping beaches and smooth running waters where hippopotamus can stand and kneel at the bottom and be close to the surface of the water for breathing and so young can be suckled easily. However, as resources are likely to vary over seasons (Western, 1975; Western and Lindsay, 1984; Fryxell and Sinclair, 1988), lakes which provide resources during the dry seasons are the preferred once. This was represented by the different sites where hippopotamus took refuge during the dry season.

Although Shita, Kerbela, Omo and Tikurewuha provided refugia to hippopotamus during the dry season, they were not as 'suitable' as , the other site of the Park because the waters were more seasonal like Tikurewuha and hence in case of prolonged drought they are likely to dry out and force the animals to disperse to other locations which are not easily available. Moving to the Omo River leads to outside the park boundary and risk of conflict with livestock and humans. At the same time the young may die due to high flooding during the wet season.

Availability of water particularly during the dry season is thought to have contributed to the observed variation in hippopotamus abundance between sites. Apart from water and forage availability, humans may also affect hippopotamus distribution and abundance (Caro *et al*., 1998). In Okavango Delta, Botswana, it was observed that hippopotamus avoided some suitable habitats due to poaching and hunting. Indigenous and crocodile hunters used hippopotamus meat as baits for crocodiles (McCarthy *et al*., 1998).

In the study area high hippopotamus variance in abundance at the Kerbela and Shita lakes may be explained by the above three factors higher conflict between hippopotamus and local community as settlements proximity to hippopotamus resting and grazing area in addition to cultivation of hippopotamus grazing land and competition with domestic animals on the same area, permanent settlements have a great disturbance on its habitat which agree with the finding of Wengström (2009). Lake Bahea being the wettest site had the highest water supply throughout the year hence maintained relatively constant hippopotamus abundance throughout the year. This is because resources mainly water and forage availability, dictates seasonal movements of mammals as mentioned by Western (1975), Western and Lindsay (1984) and Fryxell and Sinclair (1988). Also Zigna and Shoshima rivers are the best refugia for hippopotamuses during both seasons. They occur in the central Park areas which are far from the conflict and cover the majority of the Park area. Spatial variations in hippopotamus may reflect environmental variables such as water and vegetation. In Luangwa River in Zambia, hippopotamus density distribution was reported to be influenced by diversity of grass species, biomass and grazing capacity (Chansa *et al*., 2011). Wilbroad and Milanzi (2011) reported influence of grass species and abundance on hippopotamus distribution and abundance in Zambia. Harrison *et al*. (2007) reported hippopotamus abundance is related to vegetation type in Malawi.

5.3. Activitiy pattern

Existing knowledge on hippopotamus behaviour and ecology is still inadequate despite their wide distribution in Africa and their interactions with humans (Dudley, 1998). Understanding the basic behaviours of hippopotamus will aid in the care and management of populations (Eltringham, 1999 and Timbuka, 2012). As results of the present study showed, despite hippopotamus spending much of the day time resting they also performined other activities particularly those related to walking, feeding, standing and socializing. These results contradict to the previous findings conducted by Timbuka (2012) which described more than half of the day time resting. This difference may come from sampling techniques in which the present study is conducted by scan sampled individuals, compared to focal sampling. However, behavioural events or barking and yawning of hippopotamuses had some differences.

High feeding peaks in the early morning and late afternoon were as a result of low temperatures and limited disturbances by human activities, creating conducive feeding atmosphere. Ambient temperature is the main cause in reducing or even terminating grazing activity and initiating resting during the middle of the day (Grimsdell and Field, 1976; Mloszewski, 1983; Taylor, 1989; Funston *et al*., 1994). The general activity pattern of hippopotamus was characterized by morning and late afternoon peaks with a period of rest in the middle of the day. During the morning they spent some hours feeding, moving back to water and hence were unsettled. During the hot time of the day most of them were resting. This is an important adaptation for survival and keeping their skin from sun desiccation (Zubkowicz, 2005).

During mid day, hippopotamus did not try to feed except during cloudy and rainy days. Timbuka (2012) observed that hippopotamus keep on moving and get into water frequently during hot days. This is also true in our surveys that hippopotamuses did move out from the water. In CCNP, mating was observed during January and February and peak reached March which shows similar result with Magalhaes and Costa (2009). Hippopotamus mating usually happens within the dry seasons. Barking and yawning were observed at any time of the day in both males and females and mostly increased in the afternoon. This pattern is comparable to the findings of Timbuka (2012).

Hippopotamuses are primarily night time feeders (Lewison and Carter, 2004). Daytime feeding in this study may suggest that forage is limiting in CCNP. This activity of feeding might indicate that the animal had less forage during the previous night, possibly due to the distance between resting and foraging grounds or simply taking advantage of forage availability close to where they rested during the day period. It is probable that hippopotamus utilize a nearby foraging ground if available in order to meet their nutritional requirements (Blowers, 2008). Time used for travel may influence diurnal activity budgets such as animals having to rest instead of feeding. Manteca and Smith (1994) observed varied patterns as animals had to alter their activity budget as resources become scarce.

The possible reasons of various frequencies of behavioural events of male and female hippopotamus might be related to the presence of disturbance, hunger, playing, aggressive and mating events. Females were more aggressive and vocalized and defend their young offspring from the males or from possible disturbances. The female protects her calf fiercely and displays barking and yawning (Eltringham, 1999; Blowers, 2008). The reason of highest frequency of yawning and barking records of hippopotamus in April is due to the presence of mating (Eltringham, 1999). Moreover, barking and yawning events were displayed prominently in the dry months and due to competition and mating periods. This is in agreement with Jones (2008) and Timbuka (2012). Courtship is often punctuated by wheeze-honking which is the distinctive vocalization of hippopotamus (Jones, 2008)

5.4. Feeding ecology

Assessment of the quantity and quality of the most and the least eaten plant species is important to make identify the diet of herbivores (Ego *et al.*, 2003). The highest selection ratio for the species suggests that a preference for the food items that the plant species provided while low selection ratio indicates the species is not preferred (Fashing, 2001; Shah, 2003). According to Skinner and Smithers (1990), feeding preferences of hippopotamus depended on local availability of the diets. The number (40) of plant species identified as being consumed by hippopotamus in CCNP, was more comparable to the findings of Théophile *et al.* (2012) in the Biosphere Reserve of Burkina Faso (34 plant species). But, the difference in the number of plant species reported as consumed by hippopotamus in the study area and the former study might be due to the duration of study periods. This finding agrees with previous studies by Noirard *et al*. (2004) and Théophile *et al.* (2012. The foraged species were classed into graminoids, herbs, and shrubs. Among these, graminoids formed the bulk of the hippopotamus diet (66.6%) It has long been reported that their diet consisted of mainly grasses (Kingdon, 1982; Eltringham, 1999; TAWIRI, 2001). However, some current studies have reported that they feed on dicotyledons vegetation to an extent too (Boisserie *et al*., 2005; Cerling *et al*., 2008; Harris *et al*., 2008). In CCNP, hippopotamus mainly feed at night (Laws, 1968; Field, 1970; Kingdon, 1982; Eltringham, 1999; Lewison and Carter, 2004; Chansa *et al*., 2011). It has been reported that hippopotamus employ foraging strategies that respond to vegetation characteristics such as vegetation quality, quantity and distance to water source (Lewison and Carter, 2004). In the present study the major grasses including in the family Poaceae and Cyperceae were grazed both during dry and wet seasons in significant amount. This finding is similar with the previous study by Noirard *et al*. (2004) and Amoussou, *et al*. (2006)

In the present study, hippopotamus prefer to graze on short grass as close to the river and lakes. As a result, the areas close to the river and lakes are heavily grazed and badly trampled in areas where large numbers of hippopotamus are resided. Lock (1974) notes that the limitation of this animal to a belt of grassland adjacent to permanent water, and its method of grazing by plucking the grass with its lips, are potentially very damaging to grasslands. Such intense grazing on the lakes and rivers has reduced burning which in turn encourages regeneration of herbs and woody plants. Herbs cover 32.44% of the hippopotamus diet and mostly browsed during the wet season and less during the dry season. In CCNP, hippopotamuses were also sometimes eat aquatic plants, such as *Hydrocotyle mannii* with observations being made of them nibbling on floating plants as well as various types of weed which is comparable with Eltringham (1999). They occasionally eat the leaves, bark or fallen fruit of trees (Kingdon, 1979). However, no observation was made in this study as hippo eating meat of animals killed by other animals like crocodile which were reported by Eltringham (1999).

Among the plant species eaten in CCNP by hippopotamus in the present study *Cynodon dactylon*, *Cyperus rigidifolius*, *Echinochloa crusp avonis*, *Eriochloa fatmensis*, *Hydrocotyle mannii* and *Leptochloa rupestris* were the most palatable and make the major proportion of their diet. During wet and dry season which is comparable with the result of Lewison and Carter (2003) and Chansa *et al.* (2011).

Chebera Churchera National Park was covered by grass and several herbaceous plants during the whole period of the study. Despite variations in the amount of ground cover, during the driest period, at least 10 % of the ground in each site was covered with green forage. In terms of vegetation cover, forage was thus available all year in all of the sites. However, such availability depends on other sward characteristics such as minimum sward heights required for optimal foraging and bite size. Vegetation cover did not vary between sites, despite variations in wetness between sites. Rainfall in East Africa controls much of forage (McNaughton, 1985; Sinclair, 2000). The study site has long rain season. This might account for the availability of cover all year round.

Sward heights in CCNP averaged between 30 and 40 cm. This can be considered as above optimum height for hippopotamus and therefore was inaccessible for grazing during four months of the year. However, grazing pressures by other ungulates such as buffalo transform tall grasslands into patches of varying sward heights (Kanga, 2011) and hence make it accessible for foraging. In Masai Mara Game Reserve in Kenya, hippopotamus have been effective in maintaining short swards and are said to be important in vegetation dynamics (Kanga, 2011).

It has also been reported that hippopotamus feeding rate seems to be affected by sward height (Lock, 1972; Olivier and Laurie, 1974; Harrison *et al.*, 2007), preferring and foraging successfully in short grass with sward height at about 15 cm. Sward height correlated inversely with hippopotamus density for both juvenile and adults. More hippopotamuses were recorded when swards were short. However, very short swards may be also a limiting factor in the study area.

The year round greenness of forage in CCNP was partly contributed by springs, major rivers and lakes. Some areas that were burnt at the beginning of the dry season produced green shoots during the dry season. However, rainfall was a major dictating factor for plant greenness. In this study area, rainfall is extended and this was the major reason behind the greenness of plant throughout the study period which was similar with the finding of Foster and FitzGerald (1964). Hippopotamus use the short swards which rejuvenate during the course of their feeding (Shackleton, 1992). Dry periods favour the fauna whereas extremely wet ones are unfavourable (Foster and FitzGerald, 1964; O'Connor and Campbell, 1986). During the wet season, green forage may be plenty but inaccessible to animals. The grass rejuvenation principle might help to explain why green vegetation was recorded throughout the study period, in addition to water and effects of burning. Hippopotamuses do not eat selectively (Lewison, 2004) as mentioned in Meyer *et al*. (2005). It is also probable that food was available at all times.

In CCNP, the highest total plant mass was recorded in May into grassland habitat. January (the second wettest site) recorded the second highest plant mass over the whole study period. The least plant mass was recorded during wet areas. Plant biomass did not therefore correspond closely to the wetness of the site, but rather to rainfall. As it was with sward height, all the sites responded in the same way in terms of plant biomass. Wetness was however concentrated at the resting site while foraging took place at a much larger area around the shelter area. It has also been reported that forage in east Africa mainly depended on rainfall (McNaughton, 1985, Sinclair *et al*., 2000).

5.5. Human-hippopotamus conflict

The major threats of the hippopotamus around the study area were habitat degradation by expansion of agriculture and settlement, competition with livestock and killing and chasing of hippopotamuses by the local people due to crop raiding problem. UNEP-WCMC (2010) also remarked such similar threats of hippopotamus in Ethiopian water bodies. The above mentioned threat findings of the present study are also in agreement with Kanga *et al*. (2011) study in Mara River in Kenya, and Kujirakwinja (2010) Virunga National Park, Democratic Republic of Congo with potentially adverse consequences. During the present study, hippopotamuses were recoded as pests of cereal crops. Chhangani *et al*. (2008) also noted a wide variety of vertebrate pests into conflict with humans in Africa. As noted by Conover (2002) and Treves and Karanth

(2003), conflict between people and wildlife undoubtedly ranks amongst the main threats to conservation in Africa. During the study period, more than 55.9% of the respondents indicated that the most pressing problem was crop damage. These animals raid a variety of crops around the Park as a result, pattern of human-hippopotamus conflict was related to agriculture and is similar to that reported by Mkanda and Kumchedwa (1997) and Kanga *et al*. (2011a). Crop raids by hippopotamuses are unpredictable and can cause more damage per raid (Eltringham, 1993). Crop damage by hippopotamus was by feeding, by trampling and destroying certain areas of the field (Post, 2000; Kanga *et al*., 2011c). In Chewda and Delba, the problems of hippopotamuses were not recorded. This might be due to villages were far from the lakes and big rivers. In addition, the topographic features determine the movement of hippopotamus in the area. In Chebera, Churchura and Serri, the effect is less. Rainfall, season, variety and characteristics of crops, food availability, distance from forest, nearest farm or village and farm protection methods will have an impact on crop raiding by wildlife (Naughton-Treves, 1998). The present investigation also revealed that the availability, variability and type of food sources might be important factors. The raiding frequency and intensity influence the attitude of local people towards pests. Local peoples' perception of conflict does not always correspond to reality (Siex and Struhsaker, 1999).

In many parts of Africa, the conflict between local people and wildlife is the most serious problem if they are adjacent to nature reserves (Newmark *et al*., 1994). This study also shows close proximity between farms and the Park resulting in high level of conflicts. Those who live close to the habitat of the pest animals encounter high problems. As a result, those who live near the Park faced frequent crop damage. This indicated that conflicts are particularly common in reserve buffer zones where healthy wildlife populations stray from the protected areas into adjacent cultivated fields or grazing areas. This is an increasing phenomenon because the expansion of the cultivated area is very high at the periphery of protected areas (Woodroffe *et al*., 2002). Some food items/crops might be found particularly palatable and attract wildlife. For instance, according to Barnes (1996), among the crops planted outside the Kakum National Park (Ghana), maize and cassava attract particularly elephants. The present study also confirmed similar situations in the study area, in which maize and sorghum were highly preferred by most pest animals. Farmers deployed various methods to protect their farmlands from hippopotamus (Plate 4). Parker and Osborn (2006) stated that deterrents were likely to be more effective against pests. This was also true in the study area. However, the deterrent techniques were temporary because animals soon learn and ignore the threat (Bauer, 2003). Similar situation was observed in the present study. The effectiveness of methods to prevent damage by animals remains unclear.

The behaviour and preference of each pest are quite different. However, for larger animals, like hippopotamus, guarding was the sole resort to prevent crop-losses in the area. It is thus, recommended that a combination of techniques be employed in order to minimize the risk of wildlife becoming habituated to any single method. Shivik *et al.* (2003) also noted that to reduce the ability of wild animals becoming accustomed to the device, it is good to use a variety of different recorded sounds and other alternative methods. Moreover, as noted by Parker and Osborn (2006), alternative crops such as ginger and chilli have been encouraged in Zimbabwe.

As a result, farmers, who were considered to be in high-conflict area, have shifted from cultivating food crops to growing cash crops. In addition, applying fences or thorny or spiny hedges and removing nearby cover and habitat for wildlife have been recommended (Norton Griffiths 1998). Hippopotamuses are sensitive to fire and any other brightly colored objects. They are also susceptible to sound and disturbances. Low fences and ditch can easily deter them from encroaching on cultivated areas. Nostrils, eyes and ears of hippopotamuses are placed on the top the skull (Jones, 2008). Putting thorn fences at the edge of the farm and at runways of hippopotamus or entering sides of the farm might deter them. Digging deep and narrow furrows at entering sides of the farm and cover it with grasses was used as a trap. The animal will not be able to move forward or backwards and cannot come out once it enters due to their large body, massive and inflexible neck and short legs (Eltringham, 1999). This technique is used as a trap to kill the hippopotamus. Similarly, farmers that live in and around Lake Victoria used fencing materials like cedar poles and barbed wire and digging of trenches to minimize crop damage by hippopotamus (Post, 2000).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The present investigation provides valuable information on the population ecology and hippopotamus and human conflict in the study area. The distribution and habitat association of hippopotamus highly depends on vegetation cover, availability of food, water and other environmental factors and varies among habitats and between seasons. The study also revealed that a habitat with good vegetation cover and water is more suitable for hippopotamus. In addition, the information obtained in this study will also help to further detailed studies to secure the conservation activities of the Park. Generally, the study revealed the importance of the Park in harbouring diversified fauna even though the remoteness and limited accessibility of the area are barriers for further exploration. In addition, the area harbours many large mammal species, birds and other wild animals. Therefore, it can serve as important centre for conservation of the country's wildlife and tourist attraction in the future. Besides its wild animal potential, the Park has impressive landscapes and crater lakes. Human-wildlife conflict is an increasing concern in the area. As in many parts of the country, the main problem of conservation area is associated with human-wildlife conflict. At present, the major threats of the Park are crop damage and livestock loss. There is a need to develop schemes where local people perceive tangible economic benefits to tolerate wildlife on the surroundings. It is important to monitor conflict situations over time. It will help to pinpoint where the worst conflict occurs and direct deterrent efforts where they are most needed. It needs urgent action to solve the problems, otherwise the Park will no longer act as a conservation area for the wildlife as most of the National Parks of the country. There is a need for carrying out intensive awareness programmes. The data collected will provide valuable information on the ecology of hippopotamus as well as the human-hippopotamus conflict in and around CCNP.

6.2. Recommendations

- ✓ CCNP has a great potential for wildlife and tourism development. Therefore, it is necessay to take appropriate conservation measures (community based conservation activities) to minimize the problems.The studied species and others have great biological and economic values. The need for further research should be carried out to get exhaustive data.
- ✓ Monitoring activities should include regular counting of hippopotamus by the combination of ground count and aerial count indifferent habitats.
- ✓ Intensified overnight patrols in areas with high concentrations of hippopotamus should be carried out to minimize human interference.
- ✓ Specific and detailed research on different components of the biodiversity of the area is important for the proper and long-term management plan of the Park.
- ✓ Encouraging investors for infrastructure development (hotels, restaurants and lodges) in the area is important to attract both local and international tourists.
- ✓ As the Park has potential to conserve the wildlife of the country, additional budgets should be allocated from regional and/or federal government to support the overall conservation activities.
- ✓ Further research should be carried out to get detailed information on the ecology of each species.
- ✓ More incentive is needed for Park staff to increase their effectiveness.
- ✓ As the area is too large, employing additional scouts for effective and regular patrolling of the Park area is very important.
- ✓ Investigation must be carried out to identify alternative crops that do not attract wildlife.
- ✓ Awareness creation is important for the locals at different levels (on conservation, ecosystem functioning, ethical, economic and recreational values of wildlife).
- ✓ Continuous monitoring and evaluation process of human–wildlife conflict are needed for future conservation measures

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LIST OF APPENDICES

Appendix 1 Questionnaire used to interview farmers from the villages of Chebera, Serri, Yora, Shita, Churchura, Menta and Kerebela, about their experiences of crop-reading by hippopotamus.

Date Questionnaire Interviewer(s) other people present A

Village	GPS of house	GPS of farm	GPS of raided site
	S	S	S
	E	E	E

Habitat surrounding farm (was this verified by interviewer? Yes No):

- Forest River
- Housing
- Other Farms.
- Other (specify)_____

Distance to the river or lakes? ____________ Which river or lake? ___

Socio-economic information (of interviewee)

Ag:

- 18-24years
- 25–34years
- 35–44years
- 45–54 years
- 55 years or older

Gender:

- Male
- Female

What is your highest level of education?

Job: ____

1. Are you the head of the family numbers?

- Yes
- No

2. What is the size of your household?

3. What are your main sources of income?

- Agriculture
- Livestock
- Fishing
- Selling things
- Job
- Other(specif ______________________________

4. Who owns the land that you farm?

- Interviewee
- Other (specify whom)

5. How many sacks of crops do you obtain?

Agricultural characteristics

7. What is the size of your farms?

8. How long does it take to walk to your farm from your home (minutes) ?

9. What types of crops do you grow? How much of the field is each crop (ha)? How much is a sack of each crop worth Crop grown? Value per sack? How much of the field?

10. If your farm irrigated?

- Yes
- No

How much is irrigated?

11. Are you the primary worker on your fields?

- Yes
- No.

Crop damage

12. What problems do you encounter when growing your crops?

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13. Of the following animals, which are problems in terms of crop damage in your crops?

- Porcupine
- Elephant
- Commman Warthog
- African Buffalo
- Hippopotamus
- Anubis Baboon
- Bushpig.
- Vervet monkey
- Others

Are there any other animals that cause problems in the field?

14. Which animal causes the most crop damage?

Hippopotamus

15. What do you think about hippopotamus?

- Like
- Dislike
- Indifferent
- Unsure

Why? ____

16. When was the last time hippopotamus damaged or raided your crops?

- This year
- Last year
- 2–5 years ago
- _5 years ago

If not this year or last year, skip to Q. 24.

17. How often do/did hippopotamus raid your crops this year/last year (depending on answer to Q. 16)?

- Once
- Twice
- Three times
- More than three times

18. How much of your crops are/were lost to hippopotamus this year/last year (depending on answer to Q. 16) in hectare?

19. How do you know it was hippopotamus that raided your crops?

- footprint
- See the hippopotamus
- Hippopotamus dung
- Appearance of damaged vegetation
- Other (specify)

20. What time of day does crop damage from hippopotamus occur?

- Morning
- Afternoon
- Evening
- Night
- No specific time
- Unsure

21. Are there particular months when crop damage from hippopotamus has occurred more often in the last 5 years?

22. When crop damage from hippopotamus occurs what are the crop stages?

- Seedlings (1.5 feet from ground or less)
- Intermediate (2–3 feet from ground)
- Mature (taller than 3 feet, harvestable)

23. Of the crops you grow, which do hippopotamus feed on?

- Teff
- Maize
- Sorghum
- Sugar cane
- Enset
- Wheat
- Unsure

24. Have the number of crop raids by hippopotamus on your farm increased, decreased, or stayed the same in the last 5 years?

- Increased
- Decreased
- Stayed the same
- Unsure

25. Have the number of hippopotamus near your village increased, decreased, or stayed the same in the last 5 years?

- Increased
- Decreased
- Stayed the same
- Unsure

Deterrent Techniques

26. What do you do to keep animals away from your crops?

Method

- Guarding.
- Physical barriers (Thorn fences).
- Chemical repellent.
- Narrow and deep furrow.
- Others (specifiy)

If nothing, ask Q. 27.

27. Why don't you protect your crops?

- Not enough time/energy
- Not enough money.

- No need
- Protecting crops is not effective.
- Dangerous
- Other (specify)...................................

28. What else could be done to protect crops?

29. How much time per day< in planting to harvest time do you spend trying to keep animals away from your crops?

- >1 hour
- 1–5 hours
- 6–10 hours
- 11–15 hours
- 16–20 hours
- <20 hours

30. How much money do you spend trying to keep animals away from your crops each year?

31. What should happen when hippopotamus damage crops?

- Using traditional method
- Shoot them
- Farmers should be compensated
- Other (specify)

If answered shoot to Q. 31, then ask Q. 32 and skip Q. 33 and 34. If answered otherwise, skip Q. 32.

32. If the animals are shooted would you eat the meat of a hippopotamus?

- Yes
- No

What else could you use hippopotamus for?

33. If shooting is not a practice why use other solution any benefits of having hippopotamus?

- Yes
- No

  What?_____________

34. What do you want to see happen to the number of hippopotamus in the area in the next 5 years?

- Increase
- Decrease
- Stay the same
- Unsure

35. Do you have other problems with hippopotamus besides crop damage?

- Yes
- No

Are hippopotamus threats to human life?

- Yes
- No

What are the other problems?

36. Have people ever been attacked by hippopotamus?

- Yes
- No

If no, finish survey here.

37. When was the last known attack? Date__ Time of day________ Location

What happened___________________________________ Result of attack?_______

Are hippo attacks on people preventable?

- Yes
- No

How? ____

38 What should happen when hippopotamus attack people?

- Nothing
- Shoot them
- Compensation
- Other (specify) ____

If answer shoots for Q. 39, but not for Q. 31, then ask Q. 32.

Thanks for your help and participation.

Appendix 2. Species of mammals recorded in the Chebera Churchura National Park during the study period

Common name	Scientific name
Anubis baboon	*Papio Anubis*
Guereza	*Colobus gureza*
Vervet Monkey	*Cercopithecus aethiops*
Bush baby	*Gelago senegalensis*
Ground squirrel	*Xerus erythropus*
African elephant	*Loxodanta Africana*
African buffalo	*Syncerus caffer*
Hippopotamus	*Hippoptamus amphibious*
Common warthog	*Phacochoerus africanus*
Waterbuck	*Kobus ellipsipprymus*
Bushbuck	*Tragelapus scriptus*
Bush pig	*Potamochoerus larvatus*
Common Duiker	*Sylvicapra oreotragus*
Weyns duiker	*Cephalophus swensi*
Harveys duiker	*Cephalophus harveyi*
Golden Jackal	*Canis aureus*
Caracal	*Felis caracal*
Serval	*Felis serval*
Wild dog	*Lycaon pictus*
Honey Badger (Ratel)	*Mellovora capensis*
African civet	*Civettictis civetta*
White tailed mongoose	*Galerella flavescens*
Spotted hyaena	*Crocuta crocuta*
African wildcat	*Felis silvestris*
Leopard	*Panthera paradus*
Lion	*Panthera leo*
Aardvark	*Orycteropus afer*
Porcupine	*Hystrix cristata*

Appendix 3. Dominant plant species in each habitat collected and identified during the study period

Local name	Family name	Scientific name
Zainba	Arecaceae	*Phoenix reclinata*
Shimawula	Rutaceae	*Teclea nobilis*
Unknown	Fabaceae	*Dichrostachys cinerea*
Zamo	Fabaceae	*Albizia grandibracteata*
Zamo	Fabaceae	*Albizia gummifera*
Unknown	Fabaceae	*Albizia schimperiana*
Unknown	Fabaceae	*Entada abyssinica*
Unknown	Sapindaceae	*Allophylus abyssinicus*
Tuke	Rubiaceae	*Coffee Arabica*
Wogara	Oleaceae	*Olea welwitschii*
Assa Ggenbela	Moraceae	*Ficus vasta*
Bota Moruwa	Moraceae	*Ficus sur Forsk*
Unknown	Moraceae	*Ficus thoning*
Moruwa	Moraceae	*Ficus Ovata*
Atta	Moraceae	*Ficus Ovata*
Glesho Genbela	Bignoniaceae	*Terminalia brownii*
Gereche	Euphorbiaceae	*Bridelia scleroneura*
Sisa	Fabaceae	*Acacia seyal*
Dulo	Verbenaceae	*Vitex doniana*
Sobo	Combretaceae	*Combretum collinum*
Unknown	Combretaceae	*Combretum collinum*
Unknown	Combretaceae	*Combrutum paniculatum*
Unknown	Combretaceae	*Terminalia brownie*
Unknown	Combretaceae	*Combutum adengonium*
Unknown	Ulmaceae	*Celtis Africana*
Unknown	Melianthaceae	*Bersama abyssinica*
Unknown	Icacinaceae	*Apodytes dimidiate*
Digiso	Euphorbiaceae	*Combretum moll*
Geleshookashe	Costaceae	*Costus sp*
Lusha Gumre	Tilliacae	*Grewia ferrugunea*

Appendix 4. Data sheet of hippopotamus population census

Name of the data collector---------------------- Date---------------Survey site----------------

Direction of river and lake--- area of lake and river (ha) Altitude-----------Temperature (Co)

Season--------------Weather condition------------Starting time------------------Stopping time----

Key: (Ri=Sight distance, Oi= Sight angle Am=Adult male Sam= Sub adult male You= Young Af= Adult female Saf= Sub adult female Un = Unknow)

No of observ.	Obsev. Time	Sight dis& angel		Sex and age category						Total	Herd size	Animal Activity	Habitat type	Other species
		Ri	Oi	Am	Af	Sam	Sam	You	Un					

Appendix 5. Data sheet used for behavioural activity and event patterns (daily cycle)

Time of the day	Activity						
	Feeding	Walking	Resting	Standing	Barking	Yawing	Socializing*
7:00-8:00							
8:00-9:00							
9:00-10:00							
10:00-11:00							
11:00-12:00							
12:00-13:00							
13:00-14:00							
14:00-15:00							
15:00-16:00							
16:00-17:00							
17:00-18:00							

Appendix 6. Data sheet used for behavioural activity and event patterns by adult and young hippopotamus (monthly)

Months	Resting		Standing		Walking		Feeding		Yawing		Barking	
	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young	Adult	Young
Jan-09												
Feb-09												
Mar-09												
Apr-09												
May-10												
June-10												
July-10												
Aug-10												

Appendix 7. Data sheet used for behavioural activity and event patterns by male and female hippopotamus (monthly)

Months	Resting		Standing		Walking		Feeding		Yawing		Barking	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Jan-09												
Feb-09												
Mar-09												
Apr-09												
May-10												
June-10												
July-10												
Aug-10												

LIST OF PLATES

Plate 1. Interview and group discussion with different villagers

(Photo by: Aemro. M and CCNP Staffs). a-b= group discussion with local people and staff members, c-d= Interview with local people near to their home and work place

Plate 2. The effect human activites and overgrazing inside the Park

(a) = grazing of cattle inside the Park in Chebera village (b) = clearing land around the Park for shifting cultivation, (c) = agricultural activities around and in the Park in Sirri village (d) = honey production inside the Park around Shita Kebele

Plate 3. Ways of guarding crop damage by hippopotamus

(Photo by Aemro.M and park staff) (a = watch tower in Sirri village, b–d= scarecrows in Yora village, c= thorn fences in (Kerebela villge)

Plate 4. Illigal hunting of wildlife and wildlife conflict in CCNP during the study period

(Photo by: Aemro. M) (**a)** =Elephnats killed by poachers at Serri Kebel, (**b)**= Bufflo killed by poachers at Yora Kebel (**c)**=Calf bufflo taken from poached bufflo (**d)**= kid killed by lion around Churchura Kebele

Hippos at Lake Koka

Hippos at Lake Bahea

Hippos at River Zigena

Hippos at River Shoshima

Barking and aggressive fighting of hippos

Yawning Events of Hippos

Plate 5. Distrubtion and different behavioural activites of hippo in rivers and lakes of CCNP (photo by: Aemro. M and night trap Camera)

Plate 6. Lakes and Rivers of Chebera Churchura National Park

Plate 7. Different topography of CCNP (Photo by: Aemro. M and Park staffs)

Plate 8. Foraging of hippopotamus in the grassland at CCNP (photo by: Aemro.M, October, 2017)

Cynodon dactylon *Cyperus laevigatus*

Echinocloa pyramidalis *Cyperus rigidifolius*

Plate 9. Some of the grass species foraged by hippopotamus in CCNP (Photo by: Aemro. M)

Hydrocotyle mannii *Typha latifolia*

Plate 10. Some of the herb species foraged by hippopotamus in CCNP (Photo by: Aemro. M).

Plate 11. Faecal droppings of hippopotamus at Chebera Churchura National Park (Photo: Aemro.M)