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Addis Ababa University

ABSTRACT

Large Mammal Diversity and the Ecology of African Buffalo (*Syncerus caffer caffer* Sparrman, 1779) in Dhati Wolel National Park, West Ethiopia

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An investigation of the population status, habitat preference and feeding behavior of the African buffalo (*Syncerus caffer*) in Dhati Wolel National Park (DhWNP) western Ethiopia was carried out during 2013− 2014. Assessments of the population status and habitat preferences were conducted within 33 line-transects varying from 3.5 to 5 km in length, spaced throughout the Park using stratified sampling techniques. Direct observations and back-tracking assessments were carried out to study feeding behavior. The present study identified and documented 31 large mammal species in DhWNP. Among these, the globally threatened species such as Lion (*Panthera leo*), Leopard (*Panthera pardus*) and Giant forest hog (*Hylochoerus meinertzhageni*) and the rare species like Orbi (*Ourebia ourebi*), Reedbuck (*Redunca redunca*) and Spoted hyena (*Crocuta crocuta*) were recorded. High population abundance estimate (11294.5±36.005) of African buffalo was recorded. The African buffalo population in Dhati ecosystem showed a positive growth rate (11.7%) during the present study period. Habitat preference analysis showed that *S. caffer* preferred high elevation areas, dominated by savanna grasslands during the rainy season, while seasonally flooded grassland and permanent swamp of low elevation habitats were preferred during the flood season and late dry season, respectively. Among the forty-five plant species consumed by *Syncerus caffer* in the present study area, 30 species were Poacae family, while browse species constituted 15. Grass species such as *Panicum maximum, Hyparrhenia* sp., *Cynodon dactylon*, *Chloris gayana* and *Pennisetum* sp. were the principal forage component of *S. caffer* during all seasons. Intense anthropogenic activities such as shifting cultivaton, settlement, hunting and overgrazing by domestic cattle were observed in DhWNP. The extensive anthropogenic activities in an area have threatened the biodiversity of the Park and therefore, immediet actions recommended to safeguard such highly demanding ecosystem.

Key words/phrases: African buffalo, Dhati Wolel, feeding behavior, habitat analysis, large mammals, population status

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1. Introduction

1.1 Large mammal diversity

Surveying an area to prioritize for conservation relies on surrogate species measures (Margules and Pressey, 2000; Williams *et al*., 2000a; Garson *et al*., 2002). Surrogate species are umbrella species; which have ability to shape the structure and functioning of the ecosystems they inhabit. Conservation activities of such species may automatically contribute to conservation of larger proportion of ecosystems (Simberloff, 1998; Caro and O'Doherty, 1999; Andelman and Fagan, 2000). The high diversity of such species in an area will serve as a good indicator of the habitat value for biodiversity conservation (Berger *et al*., 2001; Davies and Hoffmann, 2002). Large mammal species are commonly taken as umbrella species in most ecosystems (Williams *et al*., 2000a; Davies *et al*., 2007).

Large mammals consists a wide variety of animal species from different trophic levels ranging from lower herbivores, to top carnivores (Vaughan *et al*., 2000; Davies and Hoffmann, 2002; Collier *et al*., 2007). They include mammal species starting from the size of a blue duiker (>5 kg) (Davies and Hoffmann, 2002; Kiwia, 2005). Large mammals interact in a complex and unique components in their habitats (Nowak, 1991; Berger *et al*., 2001; Wilson and Reeder, 2005). Large carnivores frequently shape the number, distribution and behavior of prey animals (Berger *et al*., 2001), while large herbivores function as ecological engineers by changing the nutrient cycle, structure and species composition of vegetation (Davies and Hoffmann, 2002; Sanderson and Trolle, 2005). Despite these, they are primarily susceptible to habitat destruction and some have declined drastically throughout their geographic ranges (Kingdon, 1997; Chapman *et al*., 2006). Natural habitats are disappearing at an alarming rate from the Earth's surface due to the expansion of human habitats (Leykun Abune, 2000; Cambel *et al*., 2002) which account for the

loss and reduction of many large mammalian species throughout the world (Kingdon, 1997; Vaughan *et al*., 2000).

Africa hosts the highest number and diversity of mammalian species in the world (Delaney and Happold, 1979; Vaughan *et al*., 2000). High diversity of large mammals is a natural feature of African tropical savanna biomes (Bourliere and Hadley, 1970; Huntley, 1982) and the present distribution of such species across the African continent is associated with the distribution of the savanna biome, with a particular concentration of species in the topographically diverse Rift Valley region of the East African savanna (Turpie and Crowe, 1994). In Ethiopia, the profound geological history, broad latitudinal spread and diverse altitudinal ranges provide remarkable broad ecological regions (Yalden, 1992) that are composed of high mammal diversity (Kingdon, 1997; Girma Mengesha and Afework Bekele, 2008; Aramde *et al.*, 2011; Melaku Tefera, 2011). Among these, most of the large mammals inhabit the southern and western lowland ecosystems of the country (Blower, 1969; Melaku Tefera, 2011). However, most of the biodiversity in the western part of Ethiopia has been given only little emphases. Hence, there is scanty information on large mammal diversity in this area hampering management actions to achieve conservation goals. So, the need to identify the diversity of large mammals in Dhati Wolel National Park, western Ethiopia is indispensible.

1.2 Population status of the African buffaloes

The African savanna biomes support a higher diversity of ungulate species (46 extant species) than any other biome of the world (Owen-Smith and Cumming, 1993; duToit and Cumming, 1999). The origin of this ungulate diversity was about 2.5 million years ago, which was probably triggered by an episode of rapid climatic change that caused widespread aridification and transition from forest to savanna (Vrba, 1992; duToit and Cumming, 1999). Among these, about

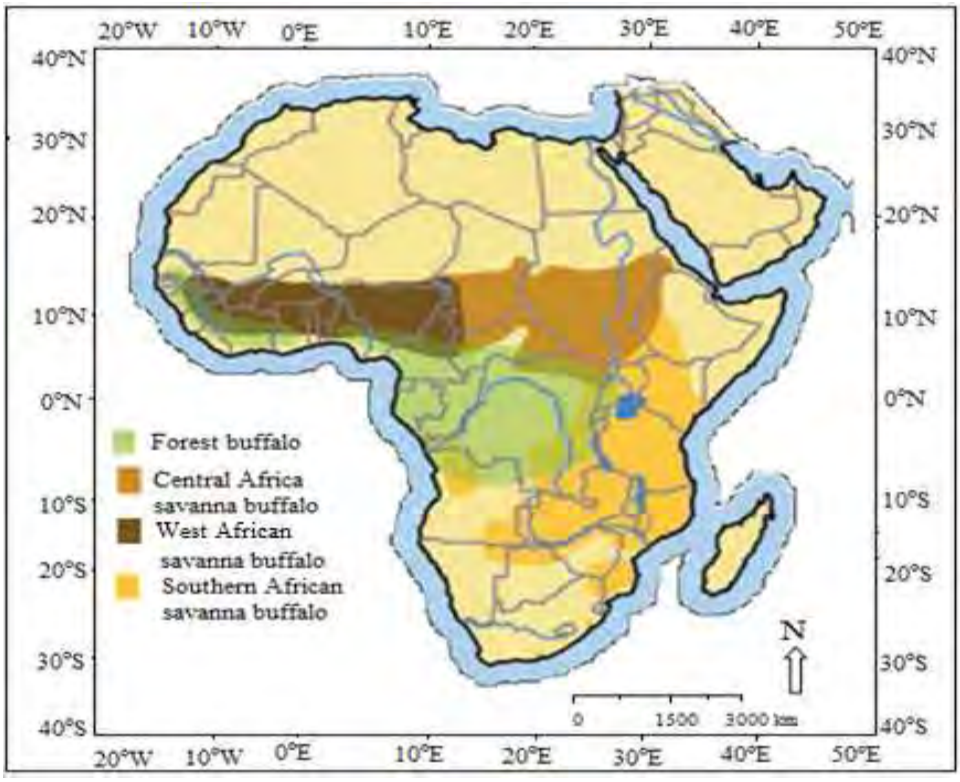
80% belong to family Bovidae (Dyson-Hudson, 1985; Owen-Smith and Cumming, 1993). African bovids are a diverse group of mammals that live in habitats ranging from tropical rain forests to deserts, and they are at present the dominant herbivores in most of African ecosystems (Vrba, 1992).

The African buffalo (*Syncerus caffer* Sparrman, 1779) is a member of the family Bovidae, subfamily *Bovinae* and tribe Bovini (Sinclair, 1977). *Syncerus caffer* was originally regarded as a type of cattle by Linnaeus in his tenth edition of *Systema Naturae* in 1758 and named it as *Bos caffer*. *Syncerus caffer* is the most recent and advanced ruminant to evolve within the last seven million years (Mloszewski, 1983; duToit, 2002). The genus *Syncerus* is endemic to the African continent, originating from either the Ethiopian highlands or the great plains of East Africa during the late Pleistocene (Prins, 1996; Winterbach, 1999; Furstenburg, 2003). The genus *Syncerus* most probably originated in the area between Lake Victoria and the horn of Africa, spreading southward and westward across the continent (Sinclair, 1977; duToit, 2002).

There were considerable differences in the genetic composition and morphological variations between the extreme ranges of *Syncerus caffer*; though there were no obvious genetic disjunctions (Sinclair, 1977; Own-Smith, 2008). The species reflects greater morphological variations across its range than all herbivore species in Africa; however, buffaloes are divided only into two definite subspecies (Skinner and Smithers, 1990; Prins 1996); the lightly built, reddish, small-horned forest buffalo, *Syncerus caffer nanus* and the heavily built, darker, big-horned savanna buffalo, *Syncerus caffer caffer* (Skinner and Smithers, 1990; Prins, 1996; duToit, 2002; Furstenburg, 2003). Beside these, in areas where the ranges of these subspecies overlap, various intermediate forms are found, and taxonomists have debated and regarded these intermediates to *Syncerus caffer aequinoctialis* and *Syncerus caffer brachyceros* (Ansell, 1972;

Mloszewski, 1983; Kingdon, 1997; duToit, 2005).

The African buffaloes are among the most successful African mammals in terms of geographical distribution, abundance and biomass (Ryan, 2006). They inhabit a wide range of habitats across Africa; from savanna grasslands to thick forests. The African buffaloes range extends over most of the African continent (Sinclair, 1977). The geographic distribution of the four familiar subspecies of African buffaloes is given as: *Syncerus caffer nanus* the smaller subspecies is found in the forests from the Ivory Coast westwards towards Liberia, *Syncerus caffer brachyceros* is a West African buffalo regarded as an intermediate subspecies, occurring from the Ivory Coast through Nigeria to Lake Chad, then southeast through southern Cameroon, Central African Republic, Congo and northwestern Democratic Republic of the Congo, *Syncerus caffer caffer*; a South African savanna buffalo, extends from southern Africa and Angola, through Central and East Africa to the southern borders of Sudan and Ethiopia. *Syncerus caffer aequinoctialis,* the Central African savanna buffalo occurs from the forests of the eastern Democratic Republic of the Congo, Lake Tanganyika and Lake Kivu and then further north to Lake Chad and eastwards to southern Sudan into Ethiopia and to the Upper Nile (Smith, 1970; Ansell, 1972; Kingdon, 1997) (Fig. 1).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(Sinclair and Grimsdell, 1982). *Syncerus caffer caffer* is the most successful of the four subspecies in terms of geographical distribution and abundance (Sinclair, 1977). This species is also widespread throughout sub-Saharan Africa, primarily in savannas with high grass biomass, but found also in high numbers in most of the major vegetation types, including dense lowland forest, montane forest and dry bush ranging from sea level to the limits of forests in the highest mountains (Sinclair, 1977; Estes, 1991; Kingdon, 1997).

The African buffaloes are highly gregarious and form large herds of 50− 500 individuals comprising mainly females and juveniles (Jolles, 2004; Turner, *et al*., 2005). The mean herd size of savannah buffalo is 350 (range from 12 to >1,500 individuals) (Sinclair, 1977; Prins, 1996; Melletti *et al*., 2007). In large herbivore population, 30 to 40% should be reproductive animals (Bothma, 2002a). In a buffalo population, a ratio of five to 15 sexually mature females per sexually active male is recommended for maximum productivity (Pienaar, 1969; Sinclair, 1977; Bothma, 2002a). In the absence of disease and anthropogenic interference, *Syncerus caffer* reach the carrying capacity in habitats where sufficient water and surplus grasses occur (Sinclair, 1977; Halley *et al.*, 2002).

Conservation status of the African buffaloes is classified as low risk, conservation dependent (IUCN, 2000). However, the species like other large mammals is subjected to population decline throughout its range (Pienaar, 1969; Sinclair, 1977; Owen-Smith, 2008). In the past, buffalo population was highly affected by a bovine disease, the rinderpest. Rinderpest is an exotic disease in Africa and African herbivores are not adapted to it (van Hooft *et al*., 2002). Historical population collapses caused by rinderpest are hypothesized to have resulted in notable genetic losses in the populations of the African buffalo (Sinclair, 1977; Estes, 1991).

In this century, the major threatening factors of the species are habitat destruction and poaching (Sinclair, 1977; Skinner and Chimimba, 2005). In Africa, loss of wildlife habitat is a widespread phenomenon restricting most of the large mammalian species in a few habitats of protected areas (Nowak, 1991; Yalden, 1992; Newmark, 2002). Habitat destruction causes the principal threat to the African buffaloes (Owen-Smith, 2008; Ogutu *et al.*, 2012); it has prevented movement between seasonal home range and between populations (Muchaa and Ngandjui, 1999; Morales *et al*., 2010). The animals are confined within a network of protected areas, loosely connected to one another resulting in genetic precipitation in the species (Njoroge *et al*., 2009). In the Serengeti ecosystem, Tanzania, the marked decline in the population of *Syncerus caffer* inside the protected area is attributed to habitat destruction (Sinclair and Arcese, 2000; Njoroge *et al*., 2009; Morales *et al*., 2010).

Poaching also has significant impact for the disappearance and population decline of large mammals, particularly the African buffalo and the African elephant (Balakrishnan, 1994). Both savanna and forest buffaloes have been greatly reduced by illegal killing for meat and trophies. Buffaloes are targeted by illegal hunters (Sinclair, 1977). Buffalo meat appears in villagers bush meat diet in most parts of Africa (Sinclair *et al*., 2002; Holmern *et al*., 2007; Hoffman *et al*., 2011). Illegal hunting has been a major cause of decline in overall trends of buffalo population (Jachmann and Billiouw, 1997; Sinclair *et al*., 2002; Hilborn *et al*., 2006). Illegal hunting remains a large threat to conservation efforts of buffalo in the Serengeti (Loibooki *et al*., 2002; Holmern *et al*., 2007). Beside these, in more arid regions, drought and its subsequent effect on food supply have been reported to be the main limiting factors regulating buffalo population (Sinclair, 1977; Skinner and Chimimba, 2005). The effect of drought becomes most pronounced when it interacts with disease (Ogutu and Owen-Smith, 2005). Poor physical condition as a result

of low quality of grazing leads to lower antibody levels in the buffalo, making it a more susceptible host for most diseases (Sinclair, 1977; Ogutu and Owen-Smith, 2005).

Despite all these threats, African buffaloes are an iconic part of the African savanna biome. Ecologically, buffaloes are significant; acting as bulk grazers to reduce tall swards in succession grazing, redistributing nutrients, initiating soil weathering by moving in large herds, hosts to a multitude of pathogens and parasites and acting as prey for Africa's large carnivores such as lions and leopards (Sinclair, 1977; Prins, 1996; Jolles, 2004). The widespread distribution and abundance as well as its high trophy value in many areas make African buffaloes an economic cornerstone of the tourist hunting industry. Photographic tourism benefits from buffaloes, as their large herds attract visitors interested in Africa's mega-herbivores and the carnivores that follow them.

African buffalo is the most prodigious and most abundant large mammal in Dhati Wolel National Park, and any ecological impact on such a flagship species will significantly impact the area. In the study area, anthropogenic influences such as hunting, habitat destruction, overgrazing and settlements have been observed within the boundary of the Park. High intensity of hunting by indigenous people is observed in the area. Though the area was left as the most wilderness area up to 2005; resettlement of people from eastern Hararghe in 2005 and 2010 led to intensive habitat destruction through shifting cultivation. Illegal settlement and farmland expansion into the forest have shrunken the woodland vegetation to the edge of wetlands. Further, sport hunting was operating for more than six years in this area without any scientific support. Despite such ecological and economic conflicts in the area, there is only scanty information on the impact of such destructive activities on wildlife diversity, abundance and distribution due to lack of research and scientific information on this ecosystem. Investigating the ecological requirements

and environmental impacts of such an umbrella species is crucial for wildlife management and conservation activities (Conner *et al*., 2003).

1.3. Habitat preference of African buffaloes

A specific relationship exists between animals and their environment (Winnie *et al*., 2008). Informations on such relationships are essential to develope wildlife management programs (Winterbach, 1999; Traill, 2004). Investigating habitat requirements of organisms provide basic information of keystone resources and help to understand the design of nature reserves (Wiens *et al*., 2011). Conservation practitioners have increasingly come to rely on models of natural systems and populations to understand species-habitat associations (Manly *et al.*, 2002; Taolo, 2003; Smith, 2011).

A habitat is a spatially abounded area, with a subset of physical and biotic features within which the density of interacting individuals is manifested (Morris, 2003; Traill, 2004). It is the suite of environmental conditions and resources that determine the presence, reproduction and survival of a species (Sinclair and Arcese, 2000). According to Traill (2004), a habitat is an area consisting of given geomorphological characteristics, including topography, soil types and vegetation, in which animals occur by choice.

Theories of habitat selection offer a variety of explicit and implicit ecological and evolutionary mechanisms (Morris, 1995; Morris and Knight, 1996; Morris and Davidson, 2000). The distribution patterns of herbivores are believed to be determined by the operation of biotic mechanisms within the constraints set by abiotic factors (Bailey *et al.*, 1996). Habitat selection in ungulates is influenced by spatial heterogeneity in their environments at scales ranging from feeding patch to biome (Sinclair, 1977; Owen-Smith, 2002; duToit *et al*., 2003). According to Sinclair (1977), habitat utilization is selective if the available habitat is used disproportionately to

its relative availability. Selection of suitable habitats by free-ranging animals is mediated by a number of fundamental requirements including suitable forage, proximity to drinking water, predator avoidance and protection from environmental extremes (Bowers, 2006). These factors may not be mutually exclusive and an animal may try and optimize the use of preferred habitats by choosing habitats that offer the greatest combinations of its key resources (Ben-Shahar, 1991; Dörgeloh, 1998; Jolles, 2007). Availability of food, size of the area available for various activities, less competition from other large herbivores, escape cover from predators and climatic extremes, surface water availability and opportunity for reproduction determine the preference of herbivores for a specific habitat type (Funstone, 1992; Mugangu *et al.*, 1995; Krüger, 1996; Lombardi *et al*., 2003).

Foraging behavior and habitat selection of African buffaloes is well documented (Sinclair, 1977; Beekman and Prins, 1989; Funston, 1992; Prins, 1996; Bennitt *et al*., 2014). African buffaloes inhabit a wide variety of habitats from sea-level to 4000 m altitude and in diverse vegetation types ranging from lowland and montane forests to moist and dry woodland savannas (Sinclair, 1977; Skinner and Smithers, 1990). Habitat utilization of African buffaloes is influenced by food distribution, food abundance and availability of water, intra-specific and inter-specific competition for food and the risk of predation (Sinclair, 1977; Prins, 1996; Bennitt, 2012). Being a large and bulky animal, buffaloes require a year-round supply of abundant grass, adequate water and shade (Estes, 1991; Owen-Smith and Cain, 2007). Buffaloes prefer habitat mosaics accessible to abundant grasses, water and dense cover throughout the year (Pienaar, 1969; Ryan and Jordaan, 2005). The five most important factors that determine the suitability of habitat for buffaloes are food, water, shade, wallows and minimal competition from other herbivores (Fryxell *et al*., 2005). They do not frequent wide open areas of grasslands/ floodplains, as they

require adequate shade for resting in the hotter parts of the day (Sinclair, 1977; Aremu, 2005). Buffaloes select vegetation to maximize nutrient intake, specifically protein (Sinclair, 1977; Beekman and Prins, 1989). Studies show that African buffaloes select areas of preferred grass species communities (Sinclair, 1977; Macandza *et al*., 2004). Vast open, grassy plains lacking woody shelter are usually avoided as are heavily over-grazed by other herbivores (Sinclair, 1977; Owen-Smith, 2008). Water accessibility is considered to be an important factor influencing large herbivore distribution (Senft *et al.,* 1987; Bailey *et al.,* 1996; Owen-Smith, 2008). Buffaloes are highly water dependant (Skinner and Smithers, 1990) and proximity to water is an essential feature of buffaloes habitat (Prins, 1996; Bowers, 2006; Macandza, 2009). Buffaloes are dependent on surface water and they have to drink water at least once every 38 hours (duToit and Ebedes, 2002). Furthermore, buffaloes also utilize water for thermoregulation during hot days (Sinclair, 1977; Mloszewski, 1983; Prins, 1996). The highest densities of buffaloes both at Klaserie and Nsiri rivers in Klaserie Private Nature Reserve, South Africa during the wet and dry seasons within 1 km of water confirms the water dependency of the species (Ryan, 2006).

Some features of a specific habitat and the habitat requirements of large herbivores change with time and space (Ben-Shahar, 1991; Dörgeloh, 1998; Owen-Smith, 2008). Seasonal rainfall in a tropical region influences the spatial distribution of herbivores by causing temporal variation in the availability of water and the productivity of particular habitats (Owen-Smith, 2008; Midgley and Thuiller, 2011). Seasonal changes include alteration in climatic conditions and phenological changes in forage availability and quality causing seasonal herbivore movement (Sinclair, 1977; Munthali and Banda, 1992; Traill, 2004). The habitats preferred by buffaloes have optimal levels of forage biomass and quality in relation to their energetic demands (Sinclair, 1977; Prins, 1996).

Seasonal changes in resource availability cause temporal changes in the profitability of a given habitat, resulting in marked seasonal patterns of habitat selection by herbivores (Bonyongo and Harris, 2007; Zweifel-Schielly *et al*., 2009). Buffaloes prefer habitats of dry areas during the rainy season (Bennitt *et al.*, 2014). During the wet season, buffaloes avoid floodplain areas due to flooding. The African buffaloes prefer habitats in hilly areas such as *Acacia* shrub and *Combretum* dominated woodlands during the wet season (Ryan *et al.,* 2006). During the rainy season, buffaloes were significantly selective to drier Mopane woodland in the Okavango Delta (Bennitt *et al*., 2014). Seasonal selection of contrasting habitats enable buffaloes to take advantage of differential profitability, while habitats that are avoided benefit from a recovery period due to reduced grazing pressure (Bowers, 2006).

Buffaloes show a preference for mid-slopes and lowlands during the dry season (Prins, 1996; Winterbach, 1999; Bowers, 2006; Macandza, 2009). The main habitat types used in lowlands are secondary floodplains, tertiary floodplains, riparian woodlands and grasslands in the interior of islands (Conneely, 2003; Bennitt *et al*., 2014). The availability of high biomass of favored forage species, lower predation risk due to better visibility and the presence of water are the contributing factors for the distribution of *Syncerus caffer* (Funston *et al*., 1994; Prins, 1996). The drying out of grass making them less palatable is the main driver for the migration to moister lowland areas containing denser patches of grass during the dry season (Sinclair, 1977). Prins (1996) reported the importance of the floodplains in providing green forage during the dry season in Lake Manyara, Tanzania. Valley bottoms have a greater accumulation of heavy clay soils and are vegetated by deeper rooted plant species to retain moisture (Morison *et al*., 1984). Clay soils, usually found in lowlands; with good soil moisture retention capacity enable grasses to retain their greenness (Macandza, 2009). Greenness of grass was the main determinant factor

for habitat utilization by large grazing ungulates at Malilangwe, with all species associating with a relatively greener grass sward (O'Reagain and Owen-Smith, 1996). A senescent, highly lignified sward is a poor food source of ungulates (Sinclair, 1975). The attraction of buffaloes to the lowland may also be influenced by higher protein levels of the grasses growing in the lowland soils (Morison *et al*., 1984; Macandza, 2009).

The effect of fire on large mammal distribution across African savannas is less doccumented (Archibald *et al*., 2005). Some large mammalian species utilize post-fire grass much later as the grass grow to preferred heights and still has high protein and phosphorous contents (Goldammer and deRonde, 2004). Buffaloes prefer savanna and increase the use of such habitat in the months following burns (Molloy, 1997). Early grass regrowth after the burn is preferred forage to some of the herbivore species because the young shoots are extremely high in protein and phosphorous, but the grass may be too short for some large herbivores (Whelan, 1995). Sinclair (1977) found that the short grass in the 'green flush' seldom attracts buffalo herds, instead, fires caused buffalo to move down the catena to lowland habitats more rapidly during the dry season. Skinner and Smithers (1990) have revealed that buffaloes are attracted to fresh grass shoot on burnt areas but they are less partial to it than most other herbivores. This may be linked to the small bite size and consequently reduced food intake rate offered by the resprouting grasses (Owen-Smith, 2002).

Bulky grazers, like the African buffaloes require large areas with sufficient resources for sustainance (Lindstedt *et al*., 1986, Macandza *et al*., 2004). However, wildlife habitats are decreasing worldwide at an accelerating rate as the human population increases (Shi *et al*., 2005). Effective management of wildlife depends on a thorough knowledge of the way in which a given species interacts with its specific environment (Leuthold, 1972; Sinclair, 1977). Habitat

selection and its associated density and frequency have a profound influence on such vital phenomena as population regulation, species interactions, assemblage of ecological communities and the maintenance of biodiversity (Morris, 2003). To manage the African buffalo population in the Dhati Wolel National Park successfully, it is crucial to understand what critical factors play a role regarding their specific habitat use. The Dhati ecosystem is a flood-pulsed ecosystem that experiences substantial seasonal variations in water levels in lowland floodplains and becomes a cause for shifts in seasonal habitat use by its mammalian inhabitants. The seasonal migration of large mammals from the floodplains during the wet season into the adjacent *Combretum-Terminalia* woodland is an integral part of the Dhati ecosystem as the wetland is fully flooded during the rainy season. However, habitat destruction and expansions of settlements have fragmented such seasonal home ranges of buffaloes. Hence, it is essential to study the habitat preference of buffaloes that contributes for further managements of the Park in terms of the preferred environmental resources.

1.4 Feeding behavior of African buffaloes

Behavioral ecology is concerned with decisions expressed by animals in the form of changes in behavior that affects their chances of survival and reproductive success (McFarland, 1977; Dale *et al*., 2005; Gaillard *et al*., 2010). Herbivores have evolved feeding behaviors to meet metabolic and reproductive requirements (Gordon, 2003). Patterns of food selection are driven by different sets of criteria at different spatial scales all of which are influenced by both ecological and physiological factors (Senft *et al.*, 1987). Feeding behavior of herbivores depends on the requirements of energy and nutrients, amount of digestible food available and the rate at which food is ingested (Dale *et al*., 2005; Codron *et al*., 2005). As herbivores rely entirely on plant materials to meet their nutrient and energy requirements (Waterman and Kool, 1994; Venter *et*

al., 2003), a further complication of their feeding behavior lies in the complex nature of savanna ecosystems where the quality and quantity of food resources vary spatially and change temporally (Bailey *et al*., 1996; Owen-Smith, 2002).

To meet nutritional requirements, animals make decisions starting from the plant species they eat, the time taken between bites and where to search for food (Gordon, 2003). Diet selection by herbivores of different feeding types corresponds with morpho-physiological adaptations of their digestive systems (vanSoest, 1996; Prins, 1996; Clauss and Hummel, 2005). These adaptations are in turn driven by fundamental physicochemical differences between food types (Holecheck, 1994, vanSoest 1996; Codron *et al*., 2005). On the basis of feeding strategies, herbivores are categorized as grazers, browsers and mixed feeders (Robbins, 1993; Hoffman and Ashwell, 2001; Gordon, 2003). Grazers primarily consume graminoid monocots (grasses and sedges), while browsers largely eat herbaceous non-grass forbs, leaves and twigs of woody plants (McNaughton and Georgiadis, 1986). Mixed feeders are intermediate between grazers and browsers, selecting a mixture of grass and browse, often seasonally switching between these food types (Gagnon and Chew, 2000).

Forage utilization by the *Syncerus caffer* has been studied at different levels: plant parts eaten (Sinclair, 1977), feeding stations, leaf table heights (Perrin and Brereton-Stiles, 1999), plant species eaten (Landman and Kerley, 2001) and landscape utilization (McNaughton *et al*., 1985; Winnie *et al*., 2008). African buffaloes are primarily grazers and due to their large body size and ruminant gut morphology, have been called bulk grazers, implying that their feeding strategy is to maximize biomass intake (Owen-Smith, 2008). The feeding behavior of buffaloes depends on access of abundant grasses and availability of water (Redfern *et al*., 2003; Skinner and Chimimba, 2005).

As ruminants, buffaloes require a combination of high quality grass and high fiber contents in their diet (Beekman and Prins, 1989; Redfern *et al.,* 2003). They select relatively nutritious grass species and parts to maximize protein and carbohydrate intake in their diets (Sinclair, 1977; McNamara and Houston, 2008). Ryan *et al*. (2007) suggested that high nitrogen content of fresh green forage is highly preferred to other herbivores. Buffaloes feed on relatively tall grass (Beekman and Prins, 1989) and avoid grass species high in secondary plant compounds (Sinclair, 1977; McNaughton, 1983; Prins, 1996; Mueller *et al*., 2008). They have massive cheek teeth, broad incisors and prehensile tongue that gather and bundle grass to feed efficiently on longer grasses (Redfern *et al.,* 2003). Grazers have the ability to select the most nutritious parts of plants, enabling them to select higher quality forage than the one randomly selected (Gagnon and Chew, 2000). Grazing ruminants predominantly focus on foraging green leaves concentrated with nutrients in order to maximize nutritional intake (McNaughton *et al*., 1985). The African buffalo has been reported to select relatively nutritious grass species and parts in order to maximize intake of proteins and carbohydrates (Sinclair, 1977; Gagnon and Chew, 2000; Macandza *et al*., 2004) and avoid grass species high in secondary metabolites, concentrating on grass species which are both high in nutrients and fiber (Perrin and Brereton-Stiles, 1999).

There are nutritional variations between grass species (Beekman and Prins, 1989) and subsequent preference to a particular or few grass species by herbivores (Gagnon and Chew, 2000; Macandza *et al.*, 2004). *Syncerus caffer* are hyper grazers, which primarily consume graminoid monocots (grasses and sedges) (Sinclair, 1977; Skinner and Smithers, 1990; Prins, 1996). Morphological and structural differences between grass species may additionally influence the rate of ingestion and nutrient assimilation, and ultimately determine species specific preferences (Owen-Smith, 1993; Owen-Smith, 2008). Variation in vegetation quality at

spatial scales has been demonstrated to affect buffalo diet quality (Sinclair and Gwynne, 1972; Sinclair, 1977; Macandza *et al*., 2004). In turn, vegetation greenness has been shown to reveal measures of plant quality important to herbivores, including crude protein concentration and neutral detergent fiber (Starks, 1986; Owen-Smith *et al*., 2010). Grass species reported to be eaten by the buffalo include *Themeda triandra, Pennisetum clandestinum, Hyparrhenia hirta, Cynodon dactylon, Panicum* sp., *Eragrotis* species, *Bothrriocloa insulpta, Setaria* sp., *Digitaria eriantha* and *Cenchrus cilliaris* (Sinclair, 1977; Macandza *et al.,* 2004). There are also species that are avoided by the buffaloes such as the lemon grass (*Cymbopogon excavatus*); may be because of its aromatic compounds (Sinclair, 1977), *Aristida* sp. and *Pogonarthria squarrosa* (Gagnon and Chew, 2000; Fryxell *et al*., 2004).

Beside the major grass components, African buffaloes are also capable of foraging a range of herbs, shrubs and browse, small twigs and young shoots (Sinclair, 1977; Landman and Kerley, 2001; Taolo, 2003; Cromhout, 2007). When pastures diminish, buffaloes extend their home range and food components (Prins, 1996; Landman and Kerley, 2001; Macandza *et al.,* 2004, Cromhout, 2007). According to the optimal foraging theory, the initially less favoured food types will be incorporated in the diet to widen diet breadths when food items become scarce (Owen-Smith and Novellie, 1982; Stephens and Krebs, 1986). Common browse species eaten by buffaloes include *Grewia bicolar, Combretum paniculatum, Euclea curvula, E. undulata, G. robusta, Ptaeroxylon obliquum, Capparis sepiaria, Portulacaria afra, Rhus longispina* and *Acacia karroo* (Sinclair, 1977; Landman and Kerley, 2001).

In savanna ecosystems, ruminants must not only obtain sufficient quality and quantity of food, but may also need to adjust their activity budget as seasonal changes constrain (Owen-Smith and Cooper, 1987; Redfern *et al.* 2003). Differences in the activity budgets and timing of activity

during the day in buffalo are hypothesized to arise due to seasonal and habitat differences (Funston *et al.*, 1994). Mammalian herbivores spend the majority of their time in feeding activity (Beekman and Prins, 1989; Redfern *et al.,* 2003). Ruminant ungulates must additionally allocate time for resting and to ruminate (Ryan and Jordaan, 2005). Seasonal changes in the quality of vegetation and availability of water have altered both the ranging and feeding habits of *Syncerus caffer* (Ryan and Jordaan, 2005; Venter *et al*., 2003). Annual cycles in ungulate feeding activity are influenced by forage quality and quantity, digestive system constraints and energy conservation needs (Leuthold, 1972; Owen-Smith, 1993).

Ruminants have a general circadian rhythm consisting of a few long feeding periods, followed by a few long ruminating and resting periods based on grass phenology and biomass (Vesey-Fitzgerald, 1974; Viljoen, 1989; Ben-shahar and Coe, 1992). Grazing and ruminating times for buffaloes vary with seasons (Grimsdell and Field, 1976; Taylor, 1989; Funston *et al*., 1994; Sinclair and Arcese, 1995). African buffaloes show a trend of allocating more time to feeding during the dry season than the wet, perhaps in response to lower vegetation quality and quantity (Sinclair, 1977; Ryan and Jordaan, 2005). Seasonal changes in the activity patterns of buffaloes were found to be governed primarily by the quality and quantity of available food (Field, 1976; Beekman and Prins, 1989; Macandza *et al.,* 2004). Beside these, the environmental constraints such as weather conditions, human activity and predation risk could also influence feeding activity of buffaloes (Mloszewski, 1983; Funston, 1992).

Understanding the difference in the utilization of food resources of herbivores is useful in explaining effective management strategies (Grant *et al*., 2000; Owen- Smith, 2002). Effective management of a species depends on a thorough knowledge of the way in which it interacts with its specific environment (Leuthold, 1972; Mloszewski, 1983; Bowers, 2006). Hence, it is also

important to determine the plant species and parts selectively consumed by African buffaloes and the factors affecting selection of those food resources to establish a baseline for monitoring the forage quality of the major grass species in the present study area.

1.5 Anthropogenic impacts

The rapidly expanding human population and improper land use practices have threatened the biodiversity throughout the World (Naeem *et al.*, 1999; Vaughan *et al.,* 2000 Hoffman and ashhwell, 2001). The expansion of human development is usually at the expense of wildlife leading to loss of habitats (Nowak, 1991; Metzger *et al*., 2010). Wildlife habitat is disappearing quickly from the Earth's surface due to human interference (Brooks *et al*., 2002; Milner-Gulland *et al*., 2003). Habitat loss has currently emerged as a most severe threat to biodiversity conservation (Naeem *et al.*, 1999; Smith and Smith, 2003). Human activities such as overgrazing, deforestation, bush fires, mining, urbanization and cultivation are the principal causes of habitat destruction (Hoffman *et al*., 2011). This condition mostly affects the large mammalian species as their conservation requires large area (Vaughan *et al.,* 2000).

Protected areas are a cornerstone of global conservation strategies but their effectiveness is threatened by the intensification of land use in surrounding areas, which isolates the protected areas and damages their ecological function (Kingdon, 1997; Chapman *et al*., 2006; Hoffman *et al*., 2011). Anthropogenic activities such as timber extraction, hunting, settlement and shifting cultivation have drastically influenced wildlife populations in the protected areas (Brashares *et al*., 2001; Metzger *et al*., 2010). For example, wolf populations of the world are dropped around 99% from historic populations (Sillero-Zubiri *et al.*, 2004). Lion populations have threatened throughout their range (Nowell and Jackson, 1996). Roan antelope (*Hippotragus equines*) is locally extinct in many areas of its range due to the loss of habitats (Campbell and Borner, 1995).

Hunting of wildlife is a significant threat to conservation of biodiversity (Milner-Gulland and Bennett, 2003). Many species of large mammals are continuing to decrease within protected areas of Africa (Brashares *et al*., 2001; Newmark, 2008) often due to illegal wildlife harvesting for meat and trophies (Milner-Gulland *et al*., 2003). The wildlife populations in west and central Africa declines consistently and some of the species are locally extirpated due to hunting (Robinson and Bennett, 2000). The major threatening factors to African buffaloes are habitat destruction and poaching (Skinner and Chimimba, 2005). Poaching has the most significant impact for the disappearance and population decline of larger mammals, particularly the African buffaloes and African elephant (Balakrishnan, 1994). Anthropogenic activities such as habitat destruction, hunting and overgrazing by domestic cattle are common in the Dhati Wolel National Park, the present study area, and hence, the proposed investigation was to collect, analyze and identify the impacts of anthropogenic activities in the area and suggest possible solutions.

2. Objectives

2.1 General objective

- The general objective of this study was to assess the ecology of African buffalo (*Syncerus caffer*) in Dhati Wolel National Park, West Wollega and Kellam Wollega Zones, western Ethiopia

2.2 Specific objectives

- To investigate large mammal species diversity of Dhati ecosystem;
- To describe the population status of *Syncerus caffer* within the Park boundary;
- To monitor the population structures of buffaloes in the study area;
- To describe herd size of buffaloes during wet and dry seasons;
- To identify the food components of buffaloes in the study area;
- To assess the nutritional status of plants grazed by African buffaloes in the Park;
- To compare forage resources of buffalo herds during different seasons;
- To identify habitat preference of buffaloes in Dhati Wolel National Park;
- To evaluate the impacts of anthropogenic activities on the biodiversity of the area;
- To recommend ecological relevance of conserving Dhati ecosystem.

2.3. Hypotheses

- High diversity of large mammals will be recorded in Dhati Wolel National Park.
- The distribution of African buffaloes can be affected by seasons.
- There is a fission-fusion group, with buffalo herd sizes changing with the season.
- Some habitats are used preferentially over others by the African buffaloes in the area.
- Grass species with high leaf to stem ratios are selectively grazed by buffaloes.
- Buffaloes selectively graze during the wet season.

- Buffalo herds use the floodplains during the dry season and woodlands during the wet season.
- High population density of buffaloes is in the study area depending upon seasons.
- Sex structure of the buffalo population in Dhati Wolel is female biased.

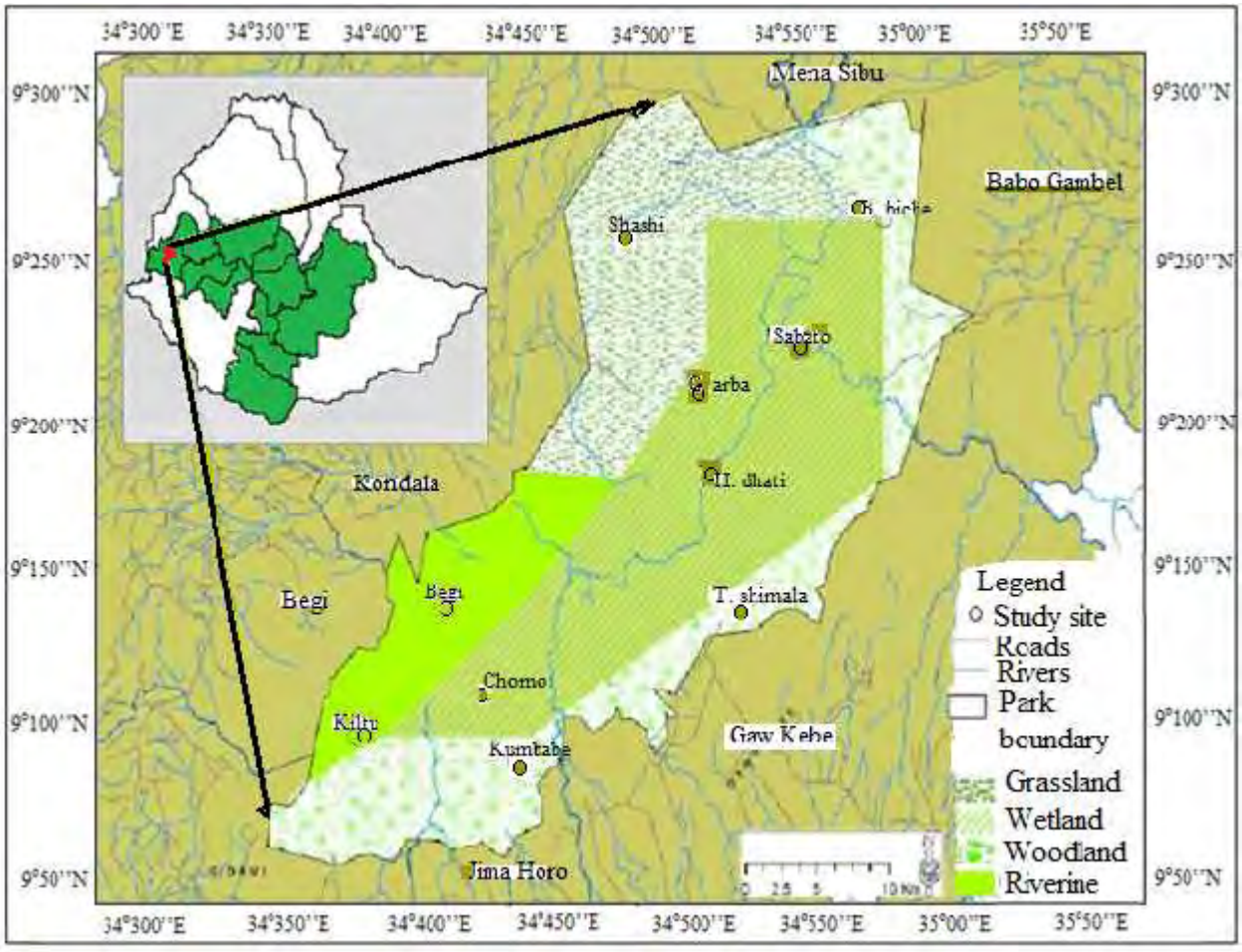
3. Materials and Methods

3.1 Description of the study area

Ethiopia contains the largest mountain blocks in Africa covering about 80% of the African highland areas above 3000 m (Yalden and Largen, 1992). The African Great Rift Valley divides these mountains into the north-western and the south-eastern highlands, and which gradually decrease in elevation to form vast arid/semi-arid lowlands towards the periphery in the east, west and southern parts of the country. The western wall of the plateau from 6^{o}N to 11^{o}N turn more to the East and fall more gradually to the West and attain their base at the border of South Sudanian plains. The southern escarpment of the plateau show general direction to southeast and to the northwest that form depression of Lake Turkana basin and Lake Rudolf basin, respectively.

Beyond the Omo River, a massive spur of the Ethiopian plateau decrease further in elevation and form an ecological barrier between the Lake Rudolf basin to the south-east and the Nile system with its diverse wetlands to the West (Blower, 1969). The Nile River and its tributaries drain a large proportion of the western and northwestern parts of Ethiopia before dropping to the plains of Sudan. The wetlands in this area stretch from the delta of Turkana in the southwest of Ethiopia, to the north along the Ethiopia-Sudan border. These wetlands include river floodplains such as Alwero, Baro, Akobo, Gilo, Beles, Lake Tana, Chomen, Fincha Swamps and Dabus Swamp.

The Dabus Swamp is formed at the headwaters of the Dabus River, following quaternary volcano-tectonic activities. It is the largest swamp in Ethiopia covering the total area of about 900 km^2 wetland habitats. This vast swamp area is currently demarcated into protected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Babo Gambel
Shashi
Sabata
arba
Kondala
Begi
Chomo
Kilty
Kumbabe
Jima Horo
Gaw Kebe
T. shimala
Legend
Study site
Roads
Rivers
Park
boundary
Grassland
Wetland
Woodland
Riverine

Horo Woreda forming a maze of meandering channels in the low floodplain areas. Many seasonal and perennial rivers join Dhati River originating from the surrounding highland areas. These include Kumbabe, Dilla, Jirma, Sadeka, Burar and Kobocha from east, southeast and southwest; while Badessa, Sholi, Sosini and other small springs flow to the floodplain from Gara-Arba Mountain in northern direction. The overflow of these rivers during the rainy season causes flooding of the wetland habitats. At the northeastern direction of this swamp, an outlet allows Dhati River to join Dilla River that flows northward from Babo-Gambel and form a big river known as Dabus River; one of the main tributaries of the Blue Nile. Ecologically, the area contains a relatively intact wetland habitat. This ecosystem composes a considerable papyrus reedland that represents a very distinct ecosystem, holding the richest habitat for the Sudan-Giunea Biome of the world's hotspot biodiversity assemblage of the country. The Park ranges in altitude from 1380 to 1500 metres above sea level. More than 80% of the Park is wetland of diversified habitats that supports high biodiversity (Tesfaye Awas, 2007).

The extensive faulting took place in the early Cenozoic, accompanied by widespread volcanic activity and led to the deposition of vast quantities of basalt over the western half of Ethiopia. While the highland areas reveal such components, the lowlands are mainly composed of basement complex rocks and metamorphic rocks, such as igneous and marble. The rocks in this area have been strongly metamorphosed due to the higher temperatures in the area. The Dabus Swamp is characterized by Alisols, Nitosols and Vertisols. All those soil features are important for wide agricultural activities and suitable for clay based cottage industries (Tesfaye Awas, 2007). The organic carbon, nitrogen and phosphorus content of the soil were higher in the wetland than in the surrounding woodland. The wetland stays moist for most of the year and anaerobic conditions in the soil lead to a buildup of organic matter, increasing the organic carbon

value. Phosphorous is washed into the wetland from the surrounding vegetation, which burns annually and accounts for the higher phosphorous content of the floodplains (Tesfaye Awas, 2007).

Most of the meteorological data for this study was collected from Bambasi and Jarso Woredas' Ethiopian National Meteological Agency stations, which are about 10−15 km away from the present study area. In most of the southern and western parts of Ethiopia, monomodal rainfall (from February to September) is experienced. Most precipitation occurs during the wet season (June through September). The minimum and maximum rainfall of the area is 1200 mm/yr and 1500 mm/yr, respectively. While the minimum and maximum temperature recorded is 20^{o}C and 25^{o}C, respectively. The maximum mean temperature record is during March and April and a lower value record was observed from July to August (Friis and Sebsebe Demissew, 2001).

During the reconnaissance survey in the present study area, different physiographic and habitat types were observed. The topography of the Park is characterized by extensive lowland plains surrounded by hills except the outlet in Northeast direction. From north, the highest altitude area of the Park called Gara-Arba, bound the lowland swampy area of this ecosystem. The vegetation of the study area is not differentiated and well defined because of lack of floral investigation in the area. However, broad habitat type classification was made depending on the occurrence of unique vegetation types and structures following the classification of vegetation regions of Ethiopia (Friis and Sebsebe Demissew, 2001).

The wetland of Dhati ecosystem contains a variety of water-adapted plant species and the woodland forest of Sudan-Guinea Savanna Biome vegetation types in Ethiopia. The Dhati swamp is comprised of several habitats, ranging from open water with submerged vegetation to emergent and surface-floating fringe vegetation, seasonally flooded grassland (toic) and

salicifolia, *Phoenix reclinata*, and species of *Acacia* and *Ficus* (Cribb *et al.*, 2002; Tesfaye Awas, 2007).

The woodland habitat has a number of floristic characteristics of undifferentiated vegetation (White, 1983). Species of *Terminalia, Combretum* and *Lannea* are common, as well as *Entada abyssinica, Erythrina abyssinica, Strychnos innocula, Anogeissus leiocarpus*, *Stereospermum kunthianum* and the solid-stemmed lowland bamboo (*Oxytenanthera abyssinica*). The ground cover is a tall stratum of perennial grasses, including species of *Cymbopogon, Hyparrhenia, Echinochloa, Sorghum* and *Pennisetum* (Sebsebe Demissew *et al*., 2005). The Dhati ecosystem supports a high diversity of wildlife. The area is a stronghold for large population of Hippopotamus (*Hippopotamus amphibius*) and African Buffalo. The Park was estabilished mainly to protect these animals (Plate 2).

On the other hand, the globally threatened and rare large mammalian species such as Lion (*Panthera leo*), Defersa waterbuck (*Kobus ellipsyprimnus*), Oribi (*Ourebia ourebi*), Reedbuck (*Redunca redunca*), Giant forest hog (*Hylochoerus meiertzhageni*), Leopard (*Panthera pardus*) Spotted Hyena (*Crocuta crocuta*) and diverse primate species are some among the many. Large part of the wetland in this Park is also habitat for wide diversity of water and water dependent birds (about 150 species) (DhWNP, 2015 unpublished report). Numerous ponds along the wetland and rivers crossing the wetland are rich in species of fish, amphibians and reptiles. However, detailed information is lacking on the ecology of these in the present study area.


A
B

animals mostly inhabit the surrounding woodland escaping the flood of the swamp habitats during the rainy season.

The impact of such anthropogenic activities on the wildlife has not yet been investigated. The African buffalo is the biggest and the most abundant species in Dhati Wolel National Park. Investigating the ecology of such a flagship species is crucial for wildlife management and conservation programe (Conner *et al*., 2003). Therefore, the present investigation was planned to provide ecological information like population abundance, feeding behavior, habitat preference of the African buffalo and anthropogenic impact in the Park to provide crucial information for the conservation and management of the Dhati Wolel National Park, western Ethiopia.

3.2 Methods

3.2.1 Large mammal diersity

Study of large mammal diversity in DhWNP was cstudied during 2013 − 2014 following systematic wildlife survey techniques (Norton-Griffith, 1978). Assessment of mammal diversity was undertaken using stratified sampling techniques in different habitats: sparsely wooded savanna grassland, riverrian forest, seasonal flooded open grassland and permanent swamp grassland. Straight-line transects were laid through samples taken using GPS. A total of 33 transects each of 3.5−5 km of 2 km wide were spaced throughout the Park covering a total of 259.3 km^2 (25.03%) of the Park. Transects were surveyed systematically with the help of traditional local hunters and currently employed scouts of the newly established Dhati Wolel National Park. They are well experienced to walk through such thick swampy habitats of the area. The already established transects were walked at constant speed, approximately 1 km/h (Struhsaker, 1975; Norton-Griffiths, 1978), and each individual or group of large mammals sighted and the indirect signs observed were recorded. Periods of walking were interspersed with

silent watch and rest to increase the possibility of detecting animals that might hide or flee upon the approach of the observer (Whiteside, *et al*., 1988). All transects were sampled once every season (wet and dry seasons) during the study periods. Most of nocturnal and lower density species were investigated using indirect signs (Willson *et al*., 1996; Long *et al*., 2007). While walking on transects, indirect sings (footprint, pugmarks, tracks scat/feces and carcasses) of large mammals observed were recorded to confirm the presence of the species.

The spotlight census of a roadside survey, in which mammals are detected by shining spotlights on either side of the road from a slow-moving vehicle was also used to obtain additional information on diversity of large mammals in the present study area using 4 WD long base Toyota vehicle of DhWNP administration. The roadside count survey consisted of driving along secondary roads in the evening or early morning and observing the eyes of animals that are reflected from the vehicle's beams or a spotlight. The "eye shine" resulting from the spotlight and subsequent "freeze" of the animal permits easy species identification (Chapman and Willner, 1986). In addition to the primary data, oral interview of indigenous people of Dhati Wolel area was made to obtain information on the history of mammal diversity of this ecosystem. Upon detection of animals; habitat types, season of the year, species name and number of individuals observed were recorded. For identification of mammal species, local expertise and *Kingdon Field Guide to African Mammals* (Kingdon, 1997) were used. Large mammal diversity of the total study area was given from direct encounters and the signs of animals observed.

3.2.2 Population status of *Syncerus caffer*

Assessment of the population size of African buffaloes was made by walking along line-transects distributed within samples taken using stratified sampling techniques (Norton-Griffiths, 1978) from different habitats in the study area (Whyte, 1996). During the present study, assessment of

the African buffaloes population status was conducted by walking on already established transects described earlier at constant speed, approximately 1 km/h (Struhsaker, 1975; Norton-Griffiths, 1978). Transects were surveyed with the help of scouts of DhWNP. Transects were walked during every season and population data were gathered.

While walking along transects, individuals and herds of *Syncerus caffer* observed were counted and the perpendicular distance from observer to animals was estimated. When a buffalo herd was located, the herd size as well as the age and sex of herd members were identified and recorded. The results from the distance sampling data were based on the following assumptions as recommended by Burnham (1990) and Danielsen *et al*. (2000): Animal positioned directly over the transect line are not missed, animals are seen before they flee, none is counted twice, animals are distributed at random with respect to transects. To prevent and minimize bias, errors and double counting, observers remained on transects during data collection and no observation was made while returning on transects as recommended by Burnham (1990).

The identification of sex and age categories was carried out using body size, pelage, external genitalia, shape and size of horn and mammary glands using a pair of binoculars. The age categories distengushed were calf (< 6 months), juvenile (6 months–2 years), sub-adult (2–5 years) and adult (>5 years). Individual buffaloes were considered as a member of the same herd if the distance between them was less than 50 m (Field, 1976; Halley *et al.*, 2002). This was also considered while recording herd size. All the data gathered during the study period were recorded on data sheet separatly in seasons and entered later to Excel computer software for further analysis.

Analysis of the population data was carried out using Distance 6.2 Release 1 software to estimate population density and herd size at 95% confidence interval (Thomas *et al*., 2010). One way

ANOVA and Post Hoc Multiple Comparison were used at $p < 0.05$ to analyze density and population structure such as age structure and sex ratios between and within the season as recommended by Steel and Torrie (1980) using SPSS statistics version 16.0. For analysis of exponential growth rate of African buffalo population, the following formula used:

$$LogNt = LogNo + rt$$

3.2.3 Habitat preference of *Syncerus caffer*

The interaction between herbivores and their environment can be analyzed qualitatively and quantitatively (Strauss, 2003). The proportion of each habitat type: *Cyperus-Thypha*; dominating the permanent swampy areas, seasonally inundated grassland; dominated by open grasslands of *Panicum-Hyparrhenia* habitat, riverian woodland, open savanna grassland habitat; dominated by grass species of *Andropogon*, *Hyparrhenia* and *Cymbopogon* and savanna grassland dominated by *Terminalia-Combretum* woodland across the study areas were determined during the reconnaissance survey across the Park areas.

Transects laid across each of these habitats were surveyed during 2013 − 2014, which was repeated during every season (Mugangu *et al.,* 1995; VonHoldt, 1999). The abundance of African buffaloes within the different habitat types was recorded by counting individuals per-habitat types to analyze habitat preferences of this species. During this investigation, same transects used during the population status survey of African buffaloes were used. Beside the abundance of buffaloes, environmental characteristics such as vegetation types, elevation, and grass greenness were also recorded to analyze for their effect on habitat preference of the African buffaloes.

For the vegetation data collection, ten 0.7 × 0.7 m^2 quadrats were placed along transects from each habitat types (five habitat types) and the collections repeated twice per habitat during every season (three seasons) providing 60 samples for seasonal effect analysis. During each sampling period, maturity states of grass and the percent of grass greenness were collected by harvesting all above ground grass within the quadrats and then sorted to green and brown/leaf litter parts by hand and subsequently dried and weighted (Shaver *et al*., 2001). In addition to the vegetation data, abiotic factors such as elevation and flood level in lowland floodplain (level of flooding) were also recorded in each season. The greenness proportion of vegetation within the quadrats was collected only during the late dry season. Before any statistical analysis was conducted, both the vegetation data and buffalo abundance were log-transformed to normalize the data.

Among the different statistical methods, the Johnson method (Johnson, 1980) is the best-suited to describe the relationship between habitat use and herbivores. The method compares ranks of habitat availability to ranks of use. This method is termed as Neu method; analyzed with the modified chi-square goodness of fit test (G-test) used to analyze if use availability ratio was different from random (Neu *et al*., 1974). The Bonferroni Z-statistics was used to construct 95% simultaneous confidence intervals that help to determine habitat preferences. Habitat selection ratios were calculated by dividing the proportion of use by the proportion of availability of each habitat (Manly *et al*., 2002) producing one value per season per habitat. Values were considered significant if their 95% confidence intervals did not include the proportional availability of the habitat type; those greater than confidence interval indicated avoidance and those less than confidence interval, indicated selection (Neu *et al*., 1974). Seasonal habitat selection ratios were subjected to Analyses of Variance (ANOVA) to determine whether they varied significantly between seasons. The effects of grass greenness, grass maturity states and elevation were

analyzed using regression analysis against the density of *S. caffer* across each habitat types. All statistical analyses were performed using SPSS, Version 16.0 (SPSS Inc., 2007)

3.2.4 Feeding behavior *Syncerus caffer*

Among several techniques of dietary analysis, direct observation method was used during the present study using a pair of 8 x 42 binoculars and unaided vision on the bases of distance and habitat types during the daylight hours. This method demands minimal equipment; however, it has a problem when there is a need to identify plant species consumed from a distance (Holechek, 1994; Codron *et al*., 2005). To quantify the vegetation in the feeding patch, backtracking method was used, where the diet of animals is identified and quantified after the animals have moved from the grazing patch (Homolka and Heroldova, 1992; Halley and Minagawa, 2005; Parker and Bernard, 2006). Plants eaten by an animal along a track are identified by the damage inflicted by a feeding animal. With the aid of foot marks and color of the part where there is the bite on the plant, one can identify grass species consumed (Perrin and Brereton-Stiles, 1999; Treydte *et al*., 2013). To minimize the impact on the herd's behavior, sampling of the patches was not undertaken immediately as the herd had finished feeding, and rather often returning later during the day, or in the case of late afternoon observations, the next morning. Data were collected only on mixed herds and the bachelors, male herds and mixed herds of less than five animals were not included as they were not considered representative of the overall activity of the buffaloes in the Park. Direct observations of a particular herd were performed sequentially and feeding sites of each herd were observed for a period of four consecutive days and repeated twice during every season.

While feeding activity was observed, data on food plants consumed were collected through backtracking that helps to quantify forage resources within qaudrats placed at the center of

feeding site to determine preferred plant species and parts across each season (Caughley and Sinclair, 1994; Wrench *et al.,* 1997). For the feeding assessment, two herds (Sabato herd and Inchinni herd) were used during the present study. In the beginning, the Chomo herd was decided to be attended for feeding behavior analysis, but as the feeding time of this herd was only observable from around 5:30 pm., which could not provide ample day light hours for data collection, a herd in Inchini area was selected. Both herds were followed for four consecutive days in the beginning and end of the three defined seasons (rainy season, flood season and late dry season) providing eight days effort to sample and quantify forage components of the study species. Within each day, 30 (0.7×0.7 m^2) quadrats were placed within feeding sites of herds and surveyed for the quantity and quality of the vegetation consumed by the study species. Food items were collected after the group had finished feeding and moved out of the site and a sample was collected and processed for identification in the Wollega University herbarium. Each grass species within the quadrat was recorded, together with its state (immature/mature/senescent), leaf height, the proportional composition of each grass species and whether it was grazed or not.

For forage quality analysis, major grass species selected by buffaloes were collected in all seasons and sun dried during the field stay, which was further oven dried at 60 ^oC at the Wollega University, Biology Department Laboratory. The dried grass samples were ground to fine powder. An acid digest was performed on the samples for analysis of N content which was further multiplied by 6.25 to get crude protein content.

Percentage of plant and parts utilized as feed was calculated for the major grass species encountered by African buffaloes to its relative availability, dietary contribution and frequency of acceptance within the quadrats and averaged to days and seasons to describe selective feeding behavior of the study species. For percentage of mature and young leaf contribution, numbers of

fresh grown and mature leaf grazed were used to calculate percentage. The impacts of physical and chemical factors of grass species were analyzed using regression analysis. Grass species acceptance was regressed against its abundance, stem to leaf ratio and crude protein content as well as the proportion of green leaves contained in species long into the dry season. The diet composition data were subjected to General Linear Model (GLM). ANOVA test was used to test for differences in the total contribution by browse and grass species during the three seasons.

3.2.5 Anthropogenic impacts

During the present study period, all signs of human activities in the DhWNP area were recorded. In addition to this, focal group discussions were made with local communities of Gawa, Guma Gara-arba and Shura Maramo residents to collect history of anthropogenic impacts in the area. Further, secondary documents that deal with human impacts in the DhWNP were collected from the surrounding Woredas' Police Office, Land and Natural Resource Protection Office and Court Office.

4. Results

The results of the present study are grouped into five sections. The first section deals with the diversity of mammals of the study area. The second section deals with the population status of African buffaloes. The third section describes habitat preferences of the African buffaloes. The fourth section deals with the feeding ecology of African buffaloes. The fifth section deals with anthropogenic impacts in the area.

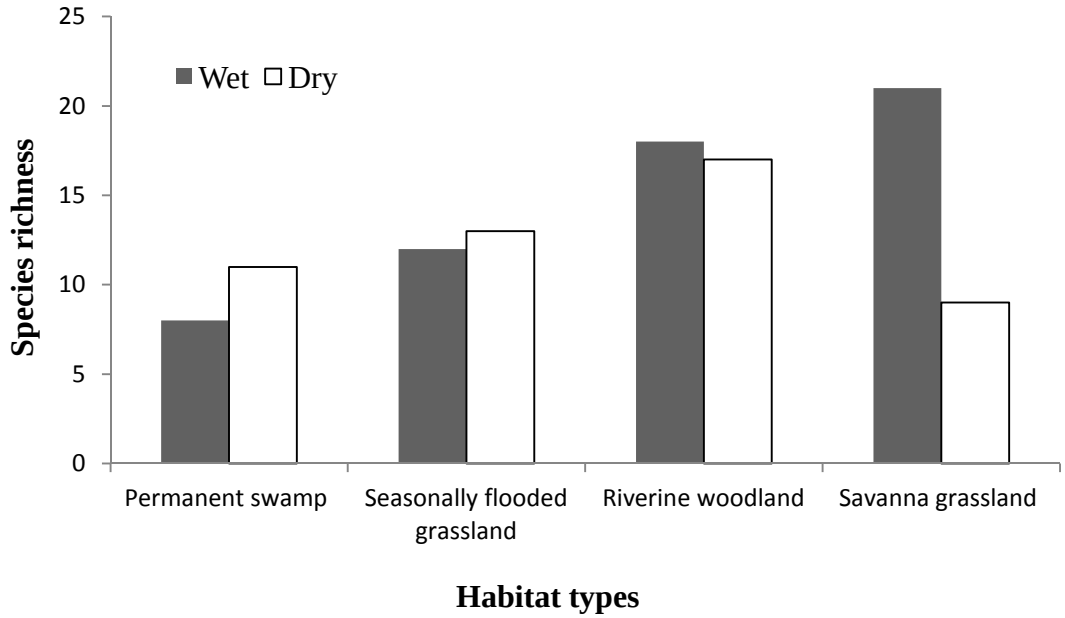
4.1 Large mammal diversity

A total of 31 species of large mammals were recorded during the present mammal survey in DhWNP. The large mammal species observed in the study area were of six orders and 14 families. Among these, order Carnivora was the most diversified taxa, comprising five families and eleven species followed by Artiodactyla constituting three families and ten species. The least diversified orders were Tubulidentata and Lagomorpha, each represented by only one species. The most diversified family of the large mammals recorded in DhWNP ecosystem was family Bovidae representing six species (*Syncerus caffer, Ourebia ourebi, Sylvicapra grimmia, Kobus ellipsiprymnus, Tragelaphus scriptus* and *Redunca redunca*), followed by Cercopithecidae (*Papio anubis, Chlorcebus aethiops, Cercopithecus mitis* and *Cercopethicus neglectus*) and Felidae (*Felis sylvestris lybica*, *Leptailurus serval*, *Panthera pardus* and *Panthera leo*) both represented by four species each. The families represented by least species were Lorisidae, Hippopotamidae, Orycteropodidae and Mustelidae, composing one species each (Table 1).

Table 1**.** Large mammal diversity of Dhati Wolel National Park, western Ethiopia in 2014

Common name	Family name	Species name	Animal sighted	Signs observed
Anubs baboon	Cercopithecidae	*Papio anubis*	✓	
Grevet monkey	Cercopithecidae	*Chlorcebus aethiops*	✓	
Blue monkey	Cercopithecidae	*Cercopithecus mitis*	✓	
DeBrazzes monkey	Cercopithecidae	*Cercopethicus neglectus*	✓	
Senegal bushbay	Lorisidae	*Galago senegalensis*	✓	
Guerza	Colobinae	*Colobus guerza*	✓	
African buffalo	Bovidae	*Syncerus caffer*	✓	
Oribi	Bovidae	*Ourebia ourebi*	✓	
Bush duiker	Bovidae	*Sylvicapra grimmia*	✓	
Waterbuck	Bovidae	*Kobus ellipsiprymnus*	✓	
Bushbuck	Bovidae	*Tragelaphus scriptus*	✓	
Reedbuck	Bovidae	*Redunca redunca*	✓	
Giant forest hog	Suidae	*Hylochoerus meiertzhageni*		✓
Common warthog	Suidae	*Phacochoerus africanus*	✓	
Bush pig	Suidae	*Potamocherus larvatus*	✓	
Hippopotamus	Hippopotamidae	*Hippopotamus amphibius*	✓	
Aardvark	Orycteropodidae	*Orycteropus afer*		✓
Honey Badger	Mustelidae	*Mellivora capensis*		✓
Spotted genet	Viverridae	*Genetta maculata*	✓	
African Civet	Viverridae	*Civetta civetta*		✓
Common Jackal	Canidae	*Canis aureus*	✓	
Black-backed Jackal	Canidae	*Canis mesomelas*	✓	
Wild cat	Felidae	*Felis sylvestris lybica*	✓	
Serval cat	Felidae	*Leptailurus serval*	✓	
Leopard	Felidae	*Panthera pardus*		✓
Lion	Felidae	*Panthera leo*	✓	
Striped hyena	Hynaenidae	*Hyena hyena*	✓	

Spotted hyena	Hynaenidae	*Crocuta crocuta*	✓	
Abyssinia hare	Leporidae	*Lepus habissincus*	✓	
Crested porcupine	Hystricidae	*Hystrix cristata*		✓



most of the primate species were recorded from riverine forest, while the majority of artiodactyls were recorded from swamp grassland and seasonal inundated grassland habitats (Table 2).

Table 2. Habitat association of large mammalian species in Dhati Wolel National Park in 2014

Species	Permanent swamp		Seasonally flooded grassland		Riverine woodland		Savanna grassland	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Papio anubis	-	-	-	-	✓	✓	✓	✓
Chlorcebus aethiops	-	-	-	-	✓	✓	✓	✓
Cercopithecus mitis	-	-	-	-	✓	✓	-	-
Cercopethicus neglectus	-	-	-	-	✓	✓	-	-
Galago senegalensis	-	-	-	-	-	✓	-	-
Colobus guerza	-		-	-	✓	✓	-	✓
Syncerus caffer			✓		✓	✓	✓	✓
Ourebia ourebi			✓		-	-	-	✓
Sylvicapra grimmia	-	-	-	-	-	-	✓	✓
Kobus ellipsiprymnus			✓		-	-	-	✓
Tragelaphus scriptus	-	-	-	-	✓	✓	-	✓
Redunca redunca			✓		-	-	-	✓
Hyochoerus meiertzhageni			✓		✓	✓	-	-
Phacochoerus africanus			✓		✓	✓	✓	✓
Potamocherus larvatus			✓		✓	✓	-	✓
Hippopotamus amphibius			✓		-	-	-	-
Orycteropus afer	-	-	-	-	✓	✓	✓	✓
Mellivora capensis	-	-	-	-	✓	✓	-	-

Genetta maculata	-		-		-		-				✓			-			-							
Civetta civetta	-		-		-						✓			✓			✓			✓				
Canis aureus	-		-				-				-			-						✓				
Canis mesomelas				-	-		-				-			-			-							
Felis sylvestris lybica		-	-		-		-				-			-						✓				
Leptailurus serval				،			✓		-			-			-					✓				
Panthera pardus	-		-				-				-			-			-							
Panthera leo				،			✓				✓			✓			✓			✓				
Hyena hyena				،			✓		-			-			-					✓				
Crocuta Crocuta				،			✓				✓			✓	-					✓				
Lepus habissincus	-		-		-				-				-				✓			✓				
Heliosciurus gambianus	-				-		-			✓	-			✓	-			-						
Hystrix cristata	-		-		-				-					✓	-					✓				

✓ = species presence, - absence of species

4.2 Population status of African buffaloes in Dhati Wolel National Park

The mean of the total individual abundance of African buffaloes observed during the present study was 2974.00. A total of 2705.5 and 3242.5 individuals were recorded in the present study area during the first and second years of the study period, respectively. The abundances recorded were not significantly different between the successive years of investigation (χ^2 = 48.00, p = 0.514) (Table 3).

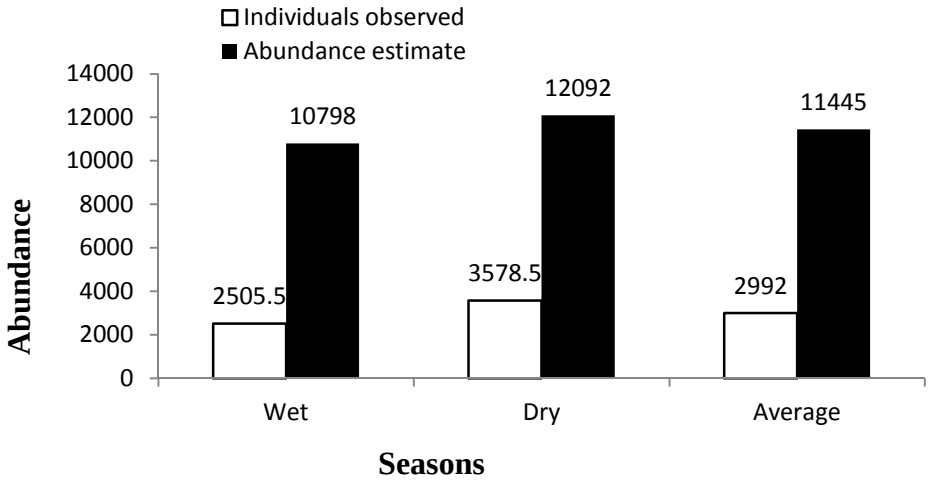
Table 3. Population of the African buffaloes observed in DhWNP from 2013-2014

Study period	Population abundance observed	
	Mean of individuals observed	Mean density ±SD
First year (2013)	2705.5±31.13	6.0251±71.755
Second year (2014)	3242.5±44.16	6.3245±38.9421
Mean	2974.0±98.17	6.1746±55.3485

Population estimate of *S. caffer* in DhWNP was 11182±50.88 and 11407±21.13 during the successive years of the study period (2013−2014). This estimate of African buffaloes did not show significant difference between the first and second years of the study period (χ^2 = 84.25, df = 20, P = 0.196). The mean density estimates of buffaloes in the study area were 0.9267 ± 33.405/km^2 and 7.7255±36.005/km^2 for groups and individuals, respectively. The growth rate calculated for buffaloes in the present study area revealed that the recruitment rate was 7.86% individuals between successive years (Table 4).

Table 4. Population estimate of *Syncerus caffer* in the Park during 2013−2014

Study period	Abundance estimate ± SE	Density estimate (group/km^2) ± SE	Density estimate (individual/km^2) ± SE
First year	11182 ±5.88	0.95562±8.62	6.694±5.88
Second year	11407±21.13	0.99784±18.29	7.757±21.13
Mean	11294.5±36.005	0.92673±33.405	7.355±16.005
Exponential growth rate		7.86%	


Individuals observed
Abundance estimate
14000
12000
10000
8000
6000
4000
2000
0
Abundance
10798
12092
11445
2505.5
3578.5
2992
Wet
Dry
Average
Seasons

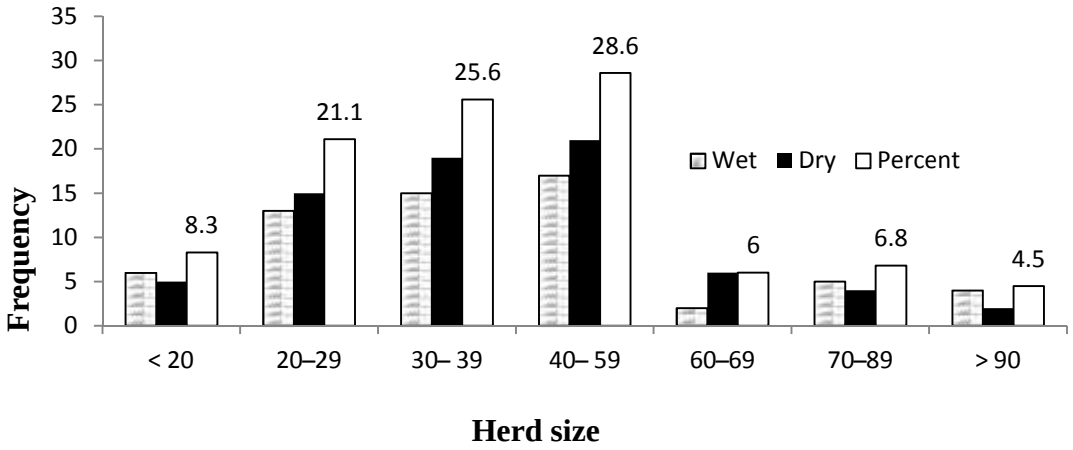


Figure 5. Herd size distribution of buffalo in Dhati Wolel National Park from 2013-2014

Table 5. Mean herd size of African buffalo in Dhati Wolel National Park from 2013-2014

Seasons	Mean ± SE.	Minimum	Maximum
Wet	34.04±3.89	8	135
Dry	43.61±2.57	6	103
Mean	38.50±2.30	7	119

During the present study, age and sex categories were assessed for 970 individuals of 23 herds during the wet season and 1071 individuals of 23 herds during the dry season. The age structure of the buffalo population in Dhati ecosystem was biased towards adults, comprising 52.38%, followed by sub-adults consisting 35.28% of the total individuals observed. The least proportion of buffaloes herd was occupied by juvenile and calve age class constituting 6.65 % and 5.68%, respectively. The mean number of adult buffaloes per herd was 17.62 ± 1.35, which occupied the largest share of the population. The least mean of the herd was occupied by calves (2.54±0.278) (Table 6).

Table 6. Age distribution of African buffaloes in Dhati Wolel National Park during different seasons from 2013-2014

Seasons	Adult	Sub-adult	Juvenile	Calves	Total
Wet	521	333	59	57	970
Dry	548	387	77	59	1071
Mean ± SD	17.62±1.3	9.83±0.8	2.98±0.3	2.5±0.3	
Proportion (%)	52.38%	35.28%	6.65%	5.68%	100.0%

The mean age structure of *S. caffer* significantly differed both during the dry (F_{dry} = 10.480, df = 3, p < 0.000) and wet (F_{wet} = 16.063, df = 3, p = 0.000) seasons. The multiple comparisons across the different age classes during the wet season revealed significant difference between adult: sub-adult, adult: juvenile and adult: calf as well as between sub-adult: juvenile and sub-adult: calf (P < 0.05). However, there were no significant differences between juvenile and calve age classes (p > 0.05). The Post Hoc comparison of the different age classes of buffaloes during the dry season also showed significant difference (p = 0.000) except for juvenile and calve age classes (p = 0.702). The mean comparison of within age classes between the different seasons did not show significant difference (p > 0.05) (F_{adult} = 0.52, $F_{subadult}$ = 0.295, $F_{juvenile}$ = 1.695, F_{calve} = 0.038).

During the present study, the sex ratio of buffaloes was dominated by females constituting 65.88% of the total population observed. In the adult age class, a ratio of 1:5.2 males to females was observed. While in the sub-adult age class, 1:1.6 sex ratio of male to female was recorded. The sex distribution of buffaloes in different seasons revealed that adult females constituted the highest percentage of the population both during the wet (45.26%) and the dry (42.63%) seasons, followed by sub-adult females (21.03%) during the wet and (22.20%) during the dry seasons.

Compared to adult and subadult females, the least proportion of buffaloes herd was constituted by adult males; 8.45% and 8.49% during the wet and dry seasons, respectively (Fig. 6).

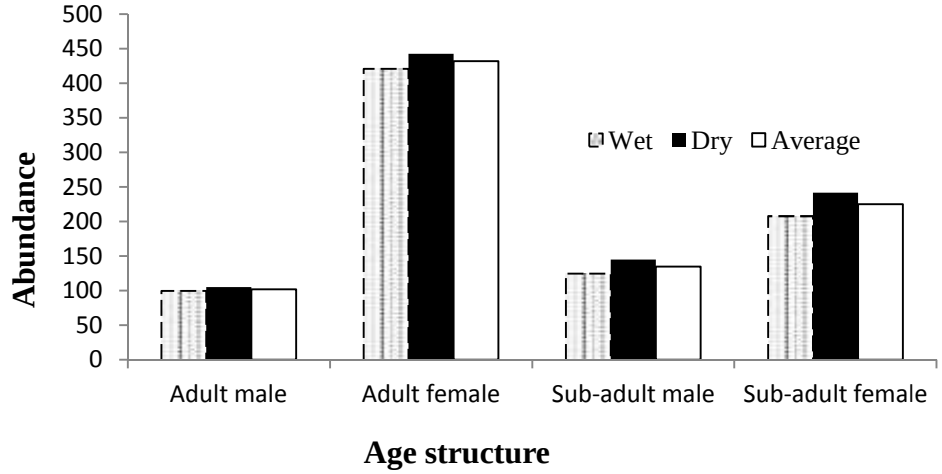
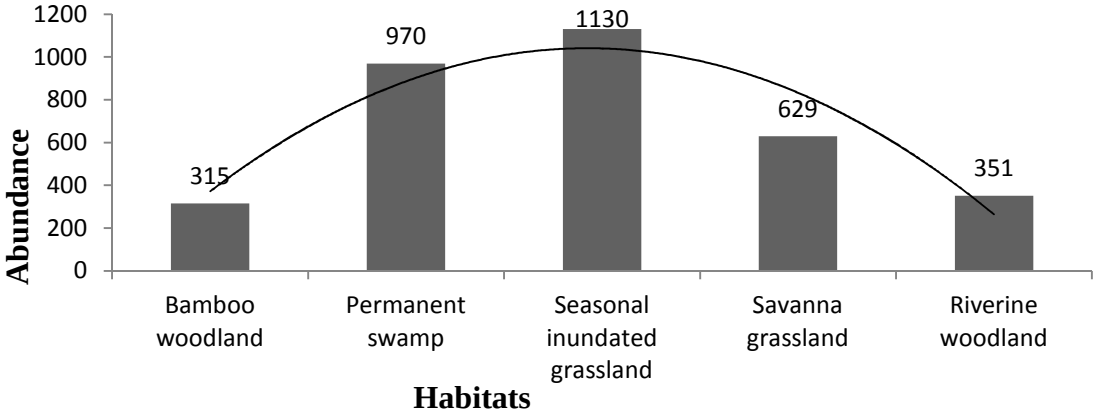


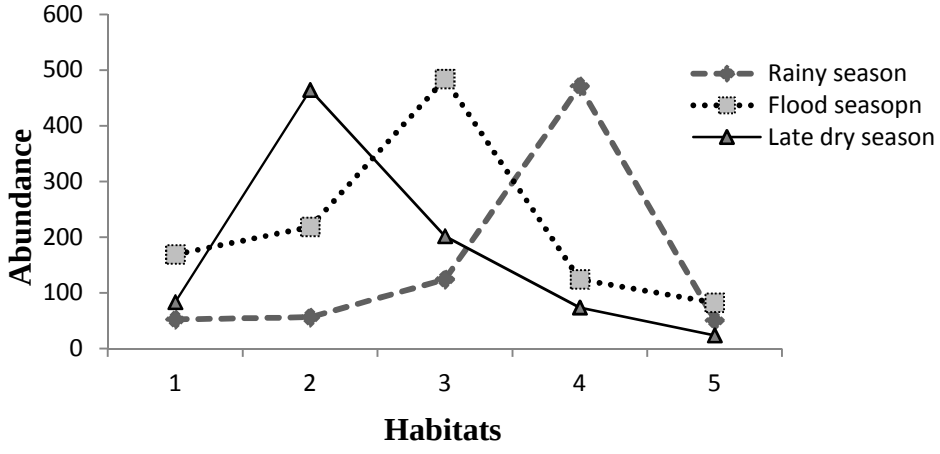
Figure 6. Sex distribution of buffaloes in DhWNP from 2013-2014

The sex structure of buffaloes was significantly different (p = 0.000) both during the wet (F = 16.866= df = 3, p = 0.000) and the dry (F = 11.751, df = 3, p = 0.000) seasons. The adult age class had a sex ratio that deviate significantly from parity during the wet (p = 0.000) and the dry (p = 0.000) seasons. However, in the subadult age class, the sex ratio did not show significant difference both during the wet (p = 0.173) and the dry (p = 0.183) seasons.

4.3 Habitat preference of African buffaloes in DhWNP

The overall analysis of the African buffalo population distribution in DhWNP across the different habitat types (permanent swamp, seasonally inundated grassland, riverine woodland, sparsely wooded savanna grassland and bamboo woodland) revealed a significant difference ($F_{5, 35}$ = 13.91, P < 0.000). The mean plot of population abundance showed the highest value in the seasonally inundated grassland habitat (33.40%), followed by the permanent swamp (28.55%), while the least abundance was recorded in bamboo woodland (9.28%) (Fig. 7).


1200
1000
800
600
400
200
0
Abundance
315
970
1130
629
351
Bamboo woodland
Permanent swamp
Seasonal inundated grassland
Savanna grassland
Riverine woodland
Habitats


600
500
400
300
200
100
0
Abundance
1
2
3
4
5
Habitats
Rainy season
Flood seasopn
Late dry season

The analysis of African buffaloes distribution throughout the Park showed significant differences in all habitat types during the different seasons of the study period ($F_{Permanent\ swamp}$ = 30.67, $F_{Seasonal\ inundated\ grassland}$ = 37.94, $F_{Savanna\ grassland}$ = 28.69, $F_{Bamboo\ woodland}$ = 12.91, 30, P = 0.000) except in riparian woodland habitat (P = 0.088). The result revealed that the permanent swamp grass and the seasonally inundated grassland were supporting significantly (P = 0.000) higher number of individuals in all seasons except during the rainy season, during which the savanna grassland supported significantly higher proportion of African buffaloes (P = 0.000).

The chi-square goodness of fit test (G^2 test) analysis revealed that the use of different habitat types by *Syncerus caffer* differed significantly (χ^2 = 5.173, df = 4, p = 0.039). Each of the habitat types in the present study area was used disproportionately to their respective size (P < 0.05). The result of analysis of variance of habitat selection ratio across all seasons was significant (p = 0.001). The separate analysis of habitat use ratio to its respective availability indicated that *S. caffer* did not use the different habitats in proportion to their availability during the flood season (χ^2 = 0.268, p = 0.008). The 95% Bonferroni corrected Z-statistics confidence interval construction of habitat selection ratio showed significant difference of habitat use from proportional availability in seasonally inundated grassland, savanna grassland, permanent swamp and bamboo woodland habitat (p = 0.000). During this period, the seasonally inundated grassland and the riverine woodland were selectively preferred (p = 0.000), while the savanna grassland habitat, the permanent swamp habitat and the bamboo woodland were significantly avoided (p = 0.000). During the rainy season, the savanna grassland habitat and bamboo woodland habitat types were selectively utilized disproportionate to their availability, however; permanent swamp and seasonally inundated grassland habitats were avoided (p = 0.000). The seasonally inundated grassland habitat and the riparian woodland habitats were used significantly

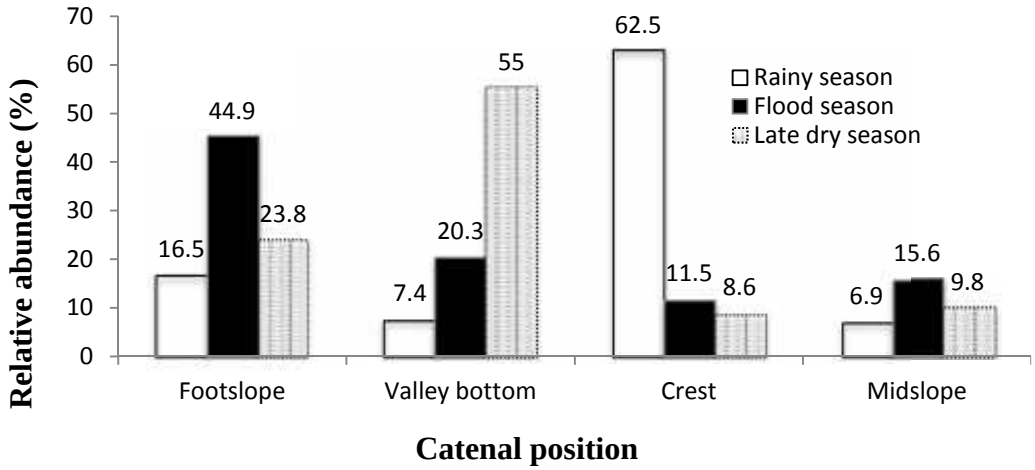
disproportionate to their availability in the flood season (p = 0.000). During the late dry season, the permanent swamp grass habitat was selectively used, while the savanna grassland habitat and the bamboo woodland habitat were significantly avoided (p = 0.000). The riparian woodland habitat type was used proportional to its respective size during most of the seasons of the present study period (p > 0.05), however, the bamboo woodland habitat was significantly avoided during both during the flood and late dry seasons; however, during the rainy season, this habitat was preferably used by *S. caffer* population of the DhWNP (p = 0.000) (Table 7).

The overall analysis of the buffaloes distribution across altitudinal gradient revealed significant results during the different seasons during the present study period (χ^2 = 22.08, df = 3, p = 0.000). The highest relative abundance of *S. caffer* was recorded from valley bottom (55.0%), followed by footslope (23.8%) during the late dry season. However, during the rainy season, the least individual abundance was recorded in these two catenal positions. During the rainy season, *S. caffer* individuals were significantly (p = 0.000) concentrated in the crest position of the sparsely wooded savanna grassland. The abundance of buffaloes recorded in midslope of the riparian woodland during the different seasons did not show significant difference ($F_{3, 6}$ = 10.2, p = 0.319) (Fig. 9).

Table 7. Habitat selection by buffaloes across different seasons during the study period from 2013-2014

Habitat types	Rainy season			Flood season			Late dry season		
	Proportion of use	Proportion of availability	Selection ratio (CI)	Proportion of use	Proportion of availability	Selection ratio (CI)	Proportion of use	Proportion of availability	Selection ratio (CI)
Permanent swamp	0.089	0.32	**(0.067-0.143)$^{-}$**	0.243	0.32	**(0.179-0.281)$^{-}$**	0.549	0.32	**(0.51-0.620)$^{+}$**
Seasonal inundated grassland	0.182	0.38	**(0.092-0.22)$^{-}$**	0.449	0.38	**(0.417-0.493)$^{+}$**	0.338	0.38	(0.285-0.394)
Savanna grassland	0.625	0.20	**(0.581-0.708)$^{+}$**	0.115	0.20	(0**.080-0.165)$^{-}$**	0.087	0.20	**(0.072-0.120)$^{-}$**
Riverine woodland	0.058	0.07	(0.049-0.072)	0.162	0.07	**(0.139-0.188)+**	0.068	0.07	(0.058-0.083)
Bamboo woodland	0.050	0.04	**(0.047-0.056)$^{+}$**	0.031	0.04	**(0.025-0.038))$^{-}$**	0.018	0.04	**(0.015-0.021)$^{-}$**

(CI)$^{+}$ = preferred habitat **(CI)$^{-}$** = avoided habitat



Figures 9. The catenal distribution of buffaloes at different seasons in DhWNP from 2013-2014

The distribution of African buffaloes was negatively correlated with high elevation of the Park areas during the late dry season (R^2 = -0.538) and flood season (R^2 = -0.324). However, in the rainy season, buffaloes were correlated positively with the high elevation of the Park (R^2 = 0.611). The Pearson chisquare analysis of green grass proportion measured from different habitats during the late dry season showed significantly higher value in the permanent swamp sedge grass habitats (χ^2 = 40.46, df = 50, p = 0.000). The regression analysis of African buffaloes distribution across the different habitat types against the proportion of green grass retained during the late dry season revealed strong positive relation (R^2 = 0.560) (Fig. 10).

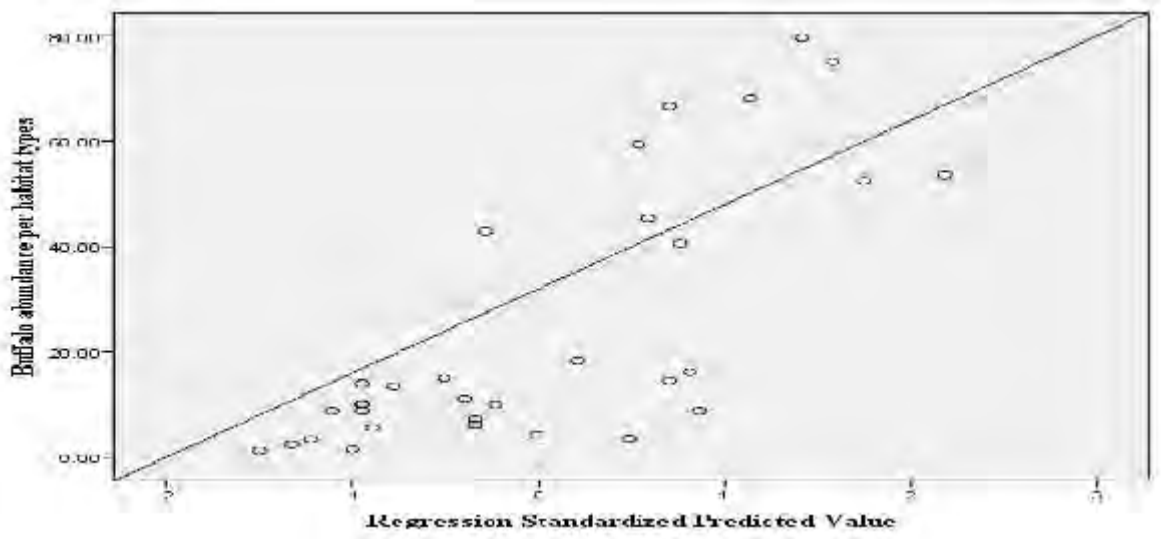


Figure 10. Comparing buffaloes's distribution to proportion of green grass in DhWNP in 2014.

4.4 Feeding behavior of *Syncerus caffer*

Direct observations and back-tracking assessment of *S. caffer* in the feeding sites during different seasons in the present study area provided 30 grass species and 15 browse species (Table 8).

Table 8. Plant species consumed by African buffaloes from DhWNP in 2014

Grass species	Browse species
Andropogon pseudopricus	*Albizia grandibracteata*
Andropogon schirensis	*Oxytenanthera abyssinica*
Brachiaria brizantha	*Macroptilium atropurpureum*
Brachiaria bracteata	*Gardenia terrifolia*
Chloris gayana	*Vernonia amygdalina*
Chloris vergata	*Dombia torrida*
Chloris pycnothrx	*Cordia africana*
Cymbopogon sp.	*Rhoicissus tridentata*
Cynodon dactylon	*Grewia villosa*
Dactyloctenium aegyptium	*Grewia bicolor*
Digitaria sp.	*Vernonia adoensis*
Echinochloa pyramidalis	*Impatiens rothii*
Eragrostis sp.	*Impatiens hochstetteri*
Hyparrhenia filipendula	*Combretum paniculatum*
Hyparnia rufa	*Grewia ferruginea*
Hyparrhenia hirta	
Leersia hexandira	
Panicum maximum	
Panicum sp.	
Pennisetum purpureum	
Pennisetum sp.	
Setaria incrassata	
Sorghum sp.	
Sporobolus sp.	
Loudetia sp.	
Cyperus latifolius	
Cyperus papyrus	
Typha sp.	
Phragmit sp.	
Scleria sp.	

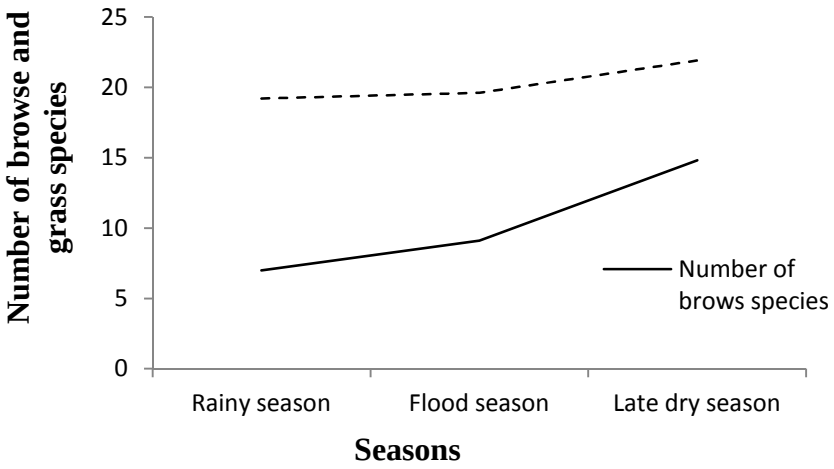

Number of browse and grass species
25
20
15
10
5
0
Number of brows species
Rainy season
Flood season
Late dry season
Seasons

Table 9. Plant species encountered by African buffaloes during the rain season in DhWNP from DhWNP in 2014

grasse species	brows species
Andropogon pseudopricus	*Dombia torrida*
Andropogon schirensis	*Grewia ferruginea*
Brachiaria brizantha	*Vernonia amygdalina*
Chloris gayana	*Grewia villosa*
Chloris pycnothrix	*Rhoicissus tridentata*
Chloris virgata	*Cordia africana*
Cymbopogon sp.	*Vernonia adoensis*
Cynodon dactylon	
Dactyloctenium aegyptium	
Digitaria sp.	
Echinochloa pyramidalis	
Eragrostis sp.	
Hyparrhenia filipendula	
Hyparrhenia hirta	
Hyparrhenia rufa	
Panicum sp.	
Panicum maximum	
Pennisetum sp.	
Setaria incrassata	
Sorghum sp.	
Sporobolus sp.	

Starting from the end of the rainy season, *S. caffer* concentrated feeding in the seasonally flooded open grassland in areas where the receding flood allowed fresh growth of grasses. During this period, 22 grass species and nine browse species were encountered by *S. caffer*. The predominantly utilized grass species of the floodplain habitats were *Panicum maximum,*

Cynodon dactylon and *Hyparrhenia* species, while the browse species used were *Grewia ferruginea, Dombia torrida* and *Vernonia amygdalina* (Table 10).

Table 10. Plant species foraged by buffaloes during the flood season from DhWNP in 2014

Grasses	Browse
Andropogon pseudopricus	*Macroptilium atropurpureum*
Brachiaria bracteata	*Impatiens hochstetteri*
Brachiaria brizantha	*Grewia ferruginea*
Chloris gayana	*Vernonia amygdalina*
Chloris sp.	*Dombia torrida*
Cynodon dactylon	*Albizia grandibracteata*
Digitaria sp.	*Grewia villosa*
Echinochloa pyramidalis	*Impatiens rothii*
Eragrostis sp.	*Rhoicissus tridentata*
Hyparrhenia bracteata	
Hyparrhenia filipendula	
Hyparrhenia hirta	
Hyparrhenia rufa	
Leersia hexandira	
Panicum maximum	
Panicum sp.	
Pennisetum unisetum	
Pennisetum purpureum	
Setaria incrassata	
Sorghum sp.	
Sporobolus sp.	

Feed items of buffaloes changed in its grass species composition with the progression of the dry season. During the late dry season, herds were grazing in the permanent swamp habitats at the bottom possition of the Park around Dhati River; the biggest river that retains sufficient water for

drinking and wallowing during such critical periods. Among the 24 grass species grazed by the buffalo population, the major ones were *Echinochloa pyramidalis*., *Cynodon dactylon*, *Leersia hexandra* and *Pennisetum* sp. The major browse species of the buffaloes during the late dry season were *Combretum paniculatum*, *Grewia villosa*, *Grewia ferruginea* and *Dombia torrida* (Table 11).

Table 11. Plant species encountered by buffaloes during late dry season from DhWNP in 2014

Grass species	browse species
Brachiaria brizantha	*Combretum paniculatum*
Brachiaria bracteata	*Macroptilium atropurpureum*
Chloris gayana	*Grewia bicolor*
Chloris virgata	*Grewia villosa*
Cynodon dactylon	*Gardenia terrifolia*
Echinochloa pyramidalis	*Grewia ferruginea*
Hyparrhenia rufa	*Vernonia amygdalina*
Hyparrhenia bracteata	*Dombia torrida*
Leersia hexandira	*Cordia africana*
Hyparrhenia hirta	*Rhoicissus tridentata*
Panicum maximum	*Albizia grandibracteata*
Pennisetum unisetum	*Oxytenanthera abyssinica*
Pennisetum purpureum	*Vernonia adoensis*
Sorghum sp.	*Impatiens rothii*
Sporobolus sp.	*Impatiens hochstetteri*
Setaria incrassata	
Andropogon pseudopricus	
Cyperus latifolius	
Cyperus papyrus	
Sorghum sp.	
Andropogon schirensis	
Phragmit sp.	
Typha sp.	
Scleria sp.	

Among the different grass species consumed by *S. caffer*, dietary preference analysis was described for nine highly grazed grass species that were observed in the feeding quadrats for

statistical analysis. The forage ratio analysis during the rainy season indicated that the grass species such as *Hyparhernia* sp., *Panicum maximum*, *Chloris gayana* and *Andropogon pseudopricus* were utilized on the basis of their relative availability (FR < 1). However, *Setaria incrassata* and *Cymbopogon* sp. were ignored by African buffaloes (Table 12).

Table 12. Grass species preference index during the rainy season from DhWNP in 2014

Grass species	A	B	C	D	E	Forage ratio (FR) and confidence intervals (CI)
Andropogon pseudopricus	231	206	0.89	0.18	0.20	0.90 (0.185-0.204)
Hyparnia sp.	219	199	0.91	0.21	0.22	0.95 (0.151-0.171)
Pennisetum sp.	143	105	0.74	0.08	0.10	0.80 (0.076-0.115)
Panicum maximum	188	*173*	0.92	0.13	0.14	0.89 (0.086-0.106)
Cymbopogon sp.	215	*73*	*0.34*	0.02	0.15	0.13 (0.135-0.154)
Digitaria erianta	123	*98*	*0.80*	0.07	0.08	0.88 (0.068-0.087)
Setaria incrassata	71	*34*	*0.48*	0.02	0.13	0.15 (0.022-0.042)
Spoobolus sp.	81	68	0.74	0.05	0.08	0.50 (0.012-0.031)
Chloris gayana	78	63	0.71	0.06	0.07	0.67 (0.018-0.037)

A = number of quadrats a species found in, B = number of quadrats a species grazed in, C = frequency of acceptance of a species, D = proportional use of a species, E = relative availability of a species.

During the flood season, significant preference (FR > 1) of grass species such as *Panicum maximum*, *Hyparnia* sp. and *Cynodon dactylon* by *S. caffer* was recorded. *Setaria incrassata* was the only grass species ignored by buffaloes during this period (Table 13).

Table 13. Grass species preference index during the flood season from DhWNP in 2014

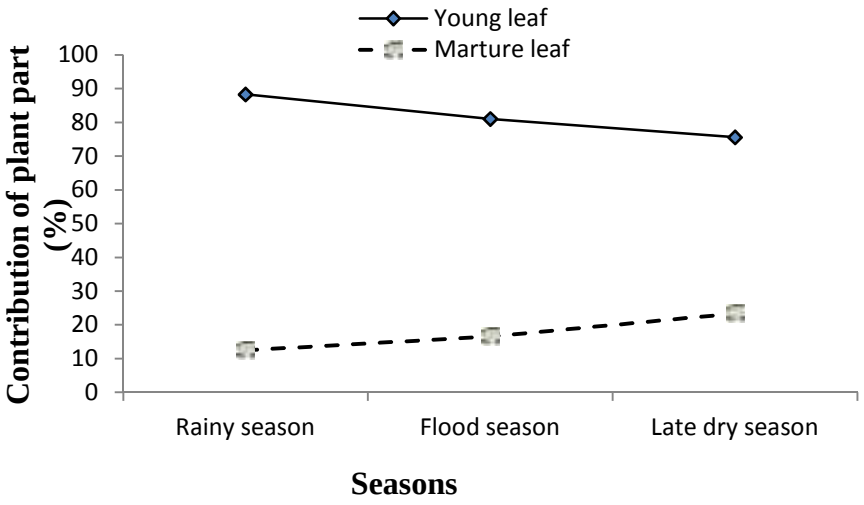
Grass species	A	B	C	D	E	Forage ratio (FR) and confidence intervals (CI)
Panicum maximum	205	193	0.94	0.22	0.20	1.10 (0.191-0.206)
Hyparnia sp.	182	162	0.89	0.17	0.16	1.06 (0.106-0.121)
Pennisetum sp.	191	120	0.63	0.05	0.12	0.42 (0.092-0.107)
Cynodon dactylon	204	190	0.93	0.12	0.08	1.50 (0.029-0.045)
Setaria incrassata	160	43	0.27	0.02	0.06	0.33 (0.055-0.070)
Leersia hexandira	207	171	0.83	0.03	0.04	0.75 (0.036-0.052)
Sporobolus sp.	168	123	0.73	0.06	0.07	0.86 (0.046-0.061)
Chloris gayana	172	139	0.78	0.07	0.08	0.78 (0.017-0.032)
Andropogon sp.	89	64	0.72	0.02	0.07	0.71 (0.010-0.025)

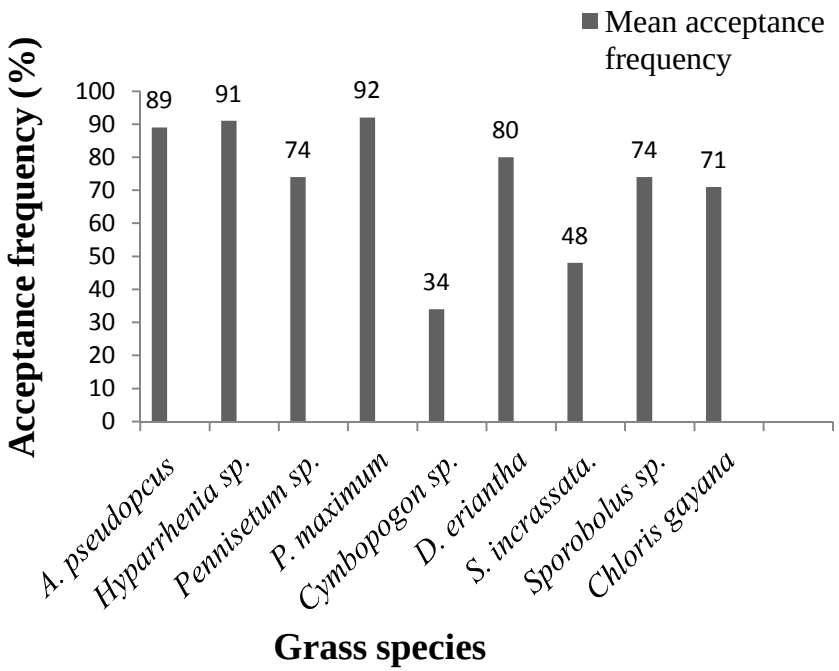
A = number of quadrats a species found in, B = number of quadrats a species grazed in, C = frequency of acceptance of a species, D = proportional use of a species, E = relative availability of a species.

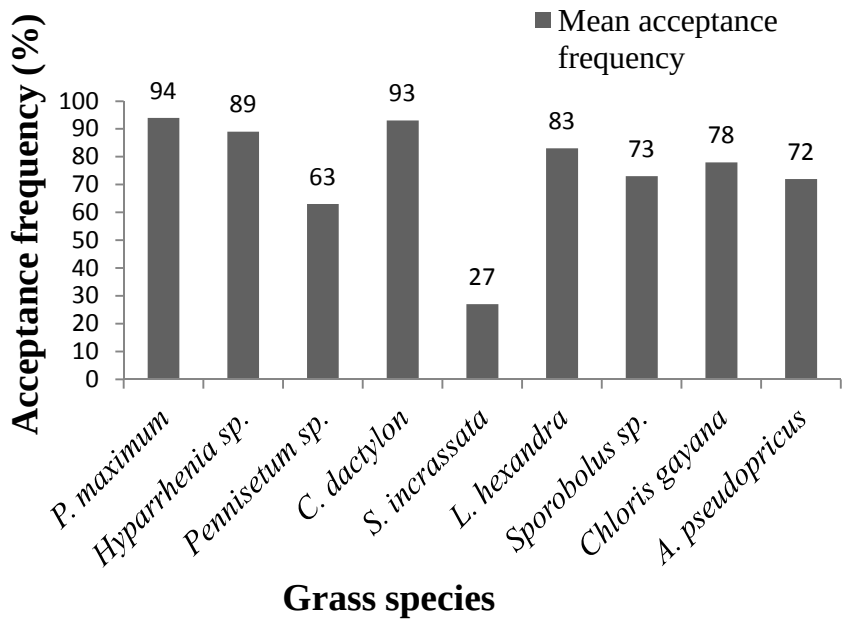
During the late dry season, grass species such as *Cynodon dactylon, Echinochloa pyramidalis, Pennisetum* sp. and *Leersia hexandira* were the most significantly (FR > 1) preferred grass species by *S. caffer*. Despite its high abundance within grazing quadrats, *Typha* sp. was the only grass species ignored during this season (Table 14).

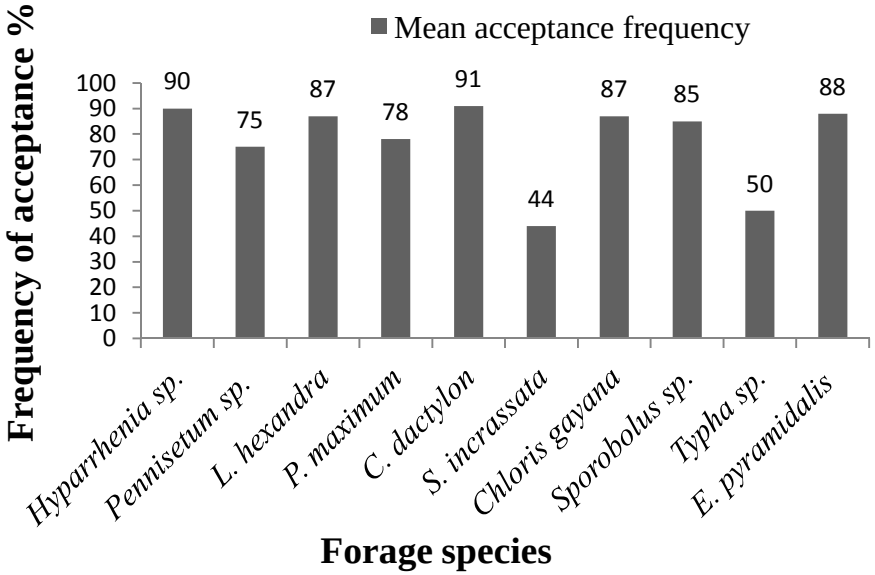
During the present study, *S. caffer* most significantly ($F_{2,\ 234} = 36.48$, $p < .000$) preferred young leaves to mature leaves throughout the study seasons. The insignificant increase in proportion of mature leaf from rainy season (12.44%) to late dry season (23.41%) was quantified ($p > .05$) in the diet of *S. caffer* in Dhati ecosystem of the present study site (Fig. 12).

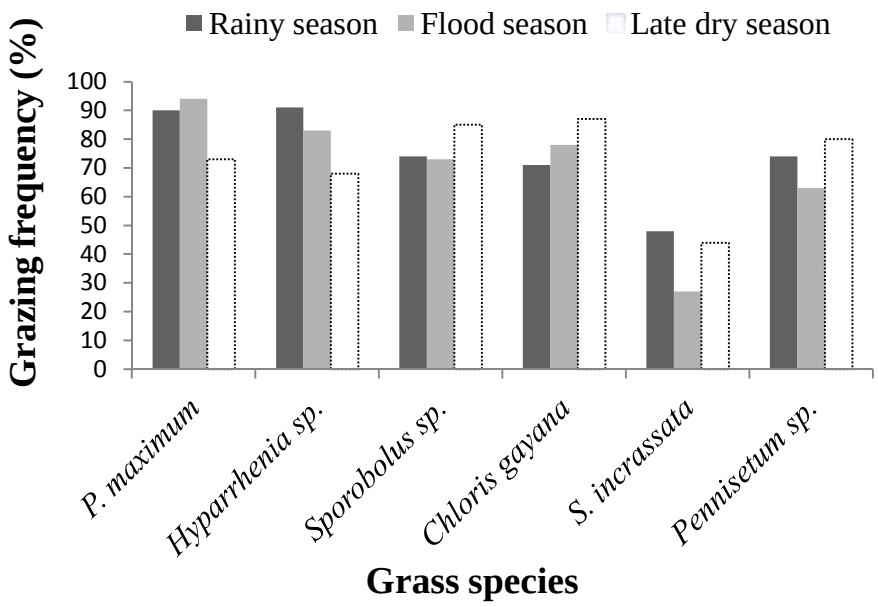
Grass species	A	B	C	D	E	Forage ratio (FR) and confidence intervals (CI)
Hyparrhenia sp.	215	194	0.68	0.14	0.17	0.83 (0.133-0.148)
Pennisetum sp.	191	143	0.75	0.17	0.18	1.06 (0.151-0.166)
Leersia hexandira	203	177	0.87	0.22	0.16	1.16 (0.082-0.097)
Panicum maximum	157	123	0.73	0.13	0.14	0.93 (0.117-0.152)
Cynodon dactylon	181	164	0.91	0.15	0.08	1.23 (0.054-0.151)
Setaria incrassata	119	52	0.44	0.09	0.08	0.33 (0.055-0.109)
Chloris gayana	89	72	0.87	0.06	0.07	0.86 (0.048-0.075)
Sporobolus sp.	120	95	0.85	0.13	0.08	0.78 (0.011-0.026)
Echinochloa pyramidalis	198	168	0.88	0.12	0.11	1.10 (0.09-0.120)
Typha sp.	128	64	0.50	0.05	0.10	0.29 (0.08-0.101)




Mean acceptance frequency
Acceptance frequency (%)
100
90
80
70
60
50
40
30
20
10
0
89
91
74
92
34
80
48
74
71
A. pseudopcus
Hyparrhenia sp.
Pennisetum sp.
P. maximum
Cymbopogon sp.
D. eriantha
S. incrassata.
Sporobolus sp.
Chloris gayana
Grass species


Mean acceptance frequency
Acceptance frequency (%)
100
90
80
70
60
50
40
30
20
10
0
94
89
63
93
27
83
73
78
72
P. maximum
Hyparrhenia sp.
Pennisetum sp.
C. dactylon
S. incrassata
L. hexandra
Sporobolus sp.
Chloris gayana
A. pseudopricus
Grass species


Mean acceptance frequency
Frequency of acceptance %
100
90
80
70
60
50
40
30
20
10
0
90
75
87
78
91
44
87
85
50
88
Hyparrhenia sp.
Pennisetum sp.
L. hexandra
P. maximum
C. dactylon
S. incrassata
Chloris gayana
Sporobolus sp.
Typha sp.
E. pyramidalis
Forage species


Rainy season
Flood season
Late dry season
Grazing frequency (%)
100
90
80
70
60
50
40
30
20
10
0
P. maximum
Hyparrhenia sp.
Sporobolus sp.
Chloris gayana
S. incrassata
Pennisetum sp.
Grass species

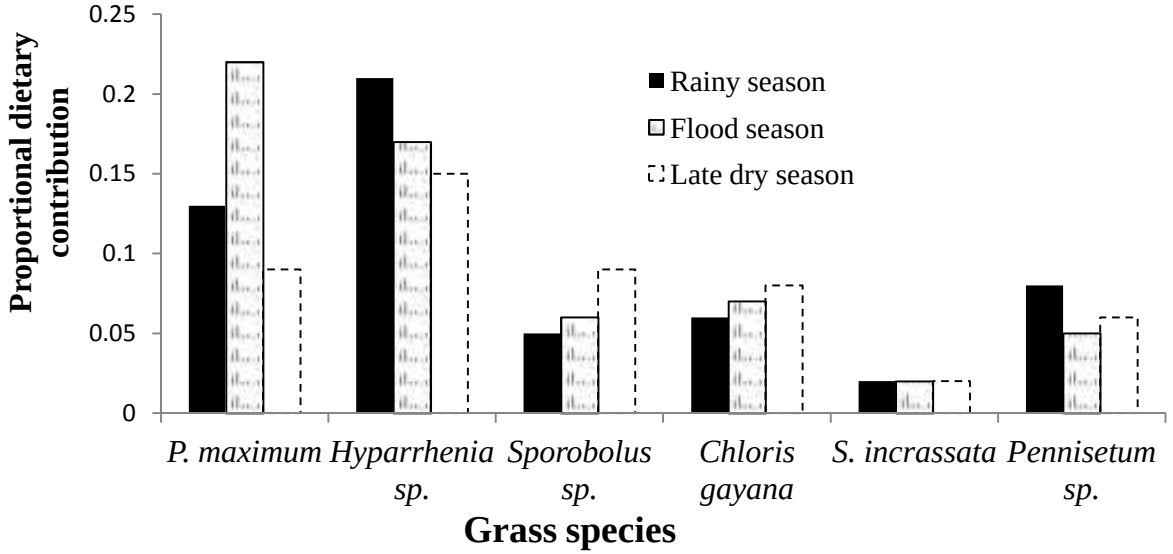
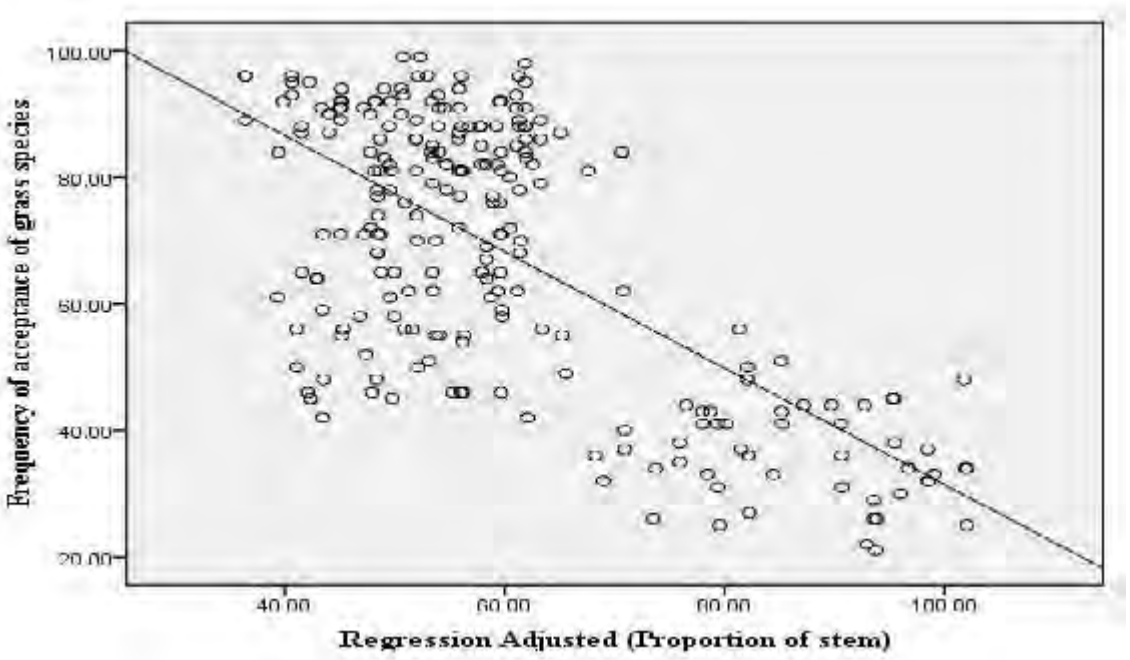
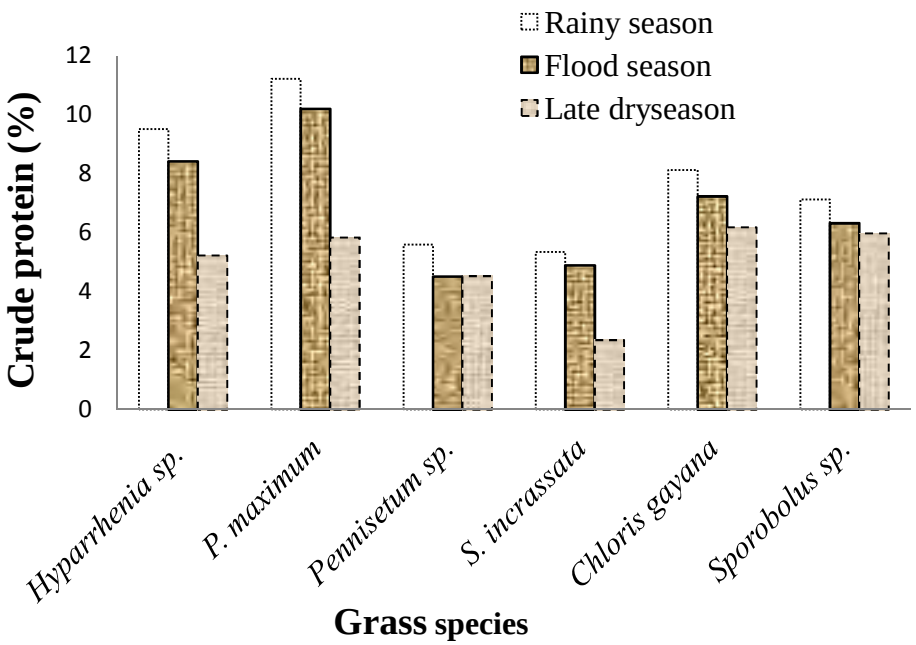


Figure 17. Dietary contribution of widely distributed grass species in DhWNP during different seasons in 2014

The grazing frequency of grass species was negatively correlated (R^2 = -.673) with the proportion of stems within grass tuft (Fig. 18). Linear relationship was observed between abundance of preferred grass species and its acceptance by *S. caffer* (Annex 3). Frequency of preferred grass species by *S. caffer* positively correlated with proportion of green leaves of the species during the late dry season (Annex 4). Regression analysis of grazing frequency with the amount of the crude protein content of each grass species revealed that African buffaloes preferred ($p < 0.05$) grass species of higher crude protein content. The regression analysis of grass species acceptance against its physical and chemical properties is given in Table 15.



Attribute of grass species	n	R^2	p - value
Grazing frequency vs. abundance of each species	320	0.825	0.000
Grazing frequency vs. stem to leaf ratios	320	-0.673	0.000
Grazing frequency vs. percent of green proportion	80	0.935	0.000
Grazing frequency vs. crude protein content of each grass species	80	0.500	0.000


Rainy season
Flood season
Late dryseason
Crude protein (%)
12
10
8
6
4
2
0
Hyparrhenia sp.
P. maximum
Pennisetum sp.
S. incrassata
Chloris gayana
Sporobolus sp.
Grass species

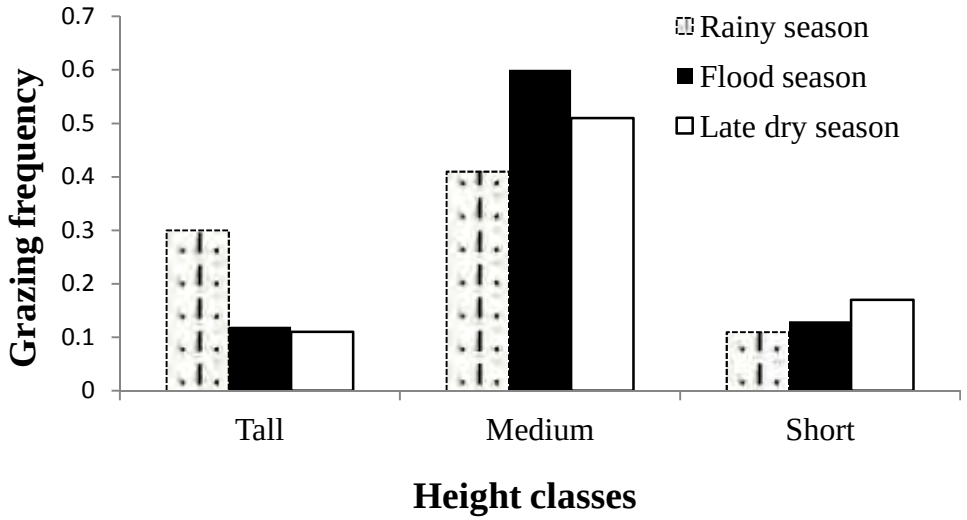


Figure 20. Preferences of grass species of different height by *Syncerus caffer* during different seasons from DhWNP in 2014

Grazing of tall grass variety did not show definit association with the frequency of grazing of grass species. *Setaria incrassata* and *Cymbopogon* sp. of tall variety were avoided; however, *Pennisetum* sp. and *Andropogon pseudopricus* of tall variety were accepted comparable to availability during during the present study.

4.5 Anthropogenic impacts

Like all other parks in Ethiopia, the Dhati Wolel National Park is also facing growing threat from human related activities. The threats observed during the present study period were wildlife poaching, shifting cultivation, settlement expansion, and livestock grazing. During the dry season, high number of domestic cattle (>10,000) were observed grazing within the Park competing with the wildlife of the area. During the dry season, pastoralists from the surrounding six Woredas temporarily settle within the Park and use the wetland habitats of the Park until the beginning of the wet season. Though the whole study area was wilderness up to 2005, the government of Oromia Regional State resettled farmers from East Hararge Zone, following the prolonged drought to West Wollega Zone in this area. Since then, the extensive *Combetum-*

The carcass observed during field work and the secondary data collected revealed that African buffaloes were hunted by poachers both for meat and cultural purposes. Hunting buffaloes fulfilled the demand for meat on social ceremonies like wedding and holidays. The community paid little money for specialist hunters on the eve of such ceremonies and got enough buffalo meat at cheaper costs.

Secondary source analysis revealed that most of the poachers (70%) come from the nearby Zones of West Wollega and Kellam Wollega sharing the boundary of the Park. Some traveled from West and North Shewa Zones about 600 km away from their villages. Poachers coming to the area from distances such as West and North Shewa Zones and East Wollega Zone were rented modern guns from the government owned local militia men (Table 16).

Table 16. Locality of poachers and the type of weapons utilized

Zones	Distance from their Zone	% of poachers in the zone	Weapons used	Source of weapons
West and Kellam Wollega	100-150 km	70%	Machine and old gun	Their own
East and Horo-Guduru Wollega	200-300 km	23%	Machine gun	Rented
West and North Shewa	500-700 km	27%	Machine gun	Rented

(Source: Guaw Kebe Woreda Police office, 2013)

Poachers from Gindaberet and North Shewa Zones came to the area as daily laborers and resided in the community near the boundary of the Park. When they went back, they killed buffaloes and took the tale to their villages. Poachers from distant places rented the weapons from government militia who held very modern machine guns such as M-14, SKS, AK-47 and others (Gauw-Kebe Woreda Police Station Report, 2014).

Following the different actions taken in cooperation with DhWNP administration and Woreda administrations around the Park boundaries, committees holding five members (Woreda Officer, Police Officer, Court Officer, Park Warden and one Scout) were established from six Woredas that border the Park. Eight criminal militias who rented their weapons to poachers were disarmed. The Oromia Forest and Wildlife Enterprise employees 12 additional scouts and currently patrol coverage increased to larger area and reached Park boundaries in Kondala, Babboo-Gambel and Jimma-Horro than the previous coverage of only in Gua-Kebe Woreda at Gawa Kamp site of the Park. The Park management plan preparation has begun and was currently on progress.

5. Discussion

5.1 Large mammal diversity

The 31 species of large mammals observed in the present study area revealed significantly higher diversity compared to 20 species of large mammals recorded from Alatish National Park, Ethiopia (Girma Mengesha and Afework Bekele, 2008), 23 species of medium and large mammal species reported from Borena-Sayint National Park, South Wollo, Ethiopia (Meseret Chane, 2010), 13 species of large mammals recorded from Ishaqibin Community Conservancy, Kenya (Muchai *et al*., 2008); 23 mammal species recorded from Arawale National Reserve, Kenya, (Njoroge *et al*., 2009), 20 species recorded from Kilombero Valley, Tanzania (Colin *et al*., 2007), 24 medium and large mammal species recorded from Katavi National Park, Tanzania (Caro, 1999). However, the result indicated relatively lower diversity compared to high diversity of larger mammals recorded in Mago National Park (81) Ethiopia (Graham *et al*., 1996), 41 from Gambella National Park Ethiopia (EWCA, 2010), 70 large mammals from Serengeti ecosystem and 57 species of large mammals in Selous Game Reserve, Tanzania (Skinner and Chimimmba, 2005). Beside the thirty one species of large mammals recorded during the present investigation, some of the high conservation value species such as red dwarf forest buffalo (*Syncerus caffer nanus*), Roan Antelope (*Hippotragus equinus*) and Lelwel Hartebeest (*Alcelaphus buselaphus lelwel*) which are listed as Endangered in the IUCN Red List of Threatened Species were also reported by local community elders around the Dhati Wolel National Park during the oral interview conducted to describe the history of large mammal diversity in the area. These species were also reported by Blower (1969) from Wollega Province of similar eco-region of the present study area.

The distribution of mammal diversity is not a smooth gradient (Kerr and Packer, 1997; Hawkins *et al*., 2003; Buckley and Jetz, 2007; Kisel *et al*., 2011). Global patterns of species richness are strongly correlated to factors of climate, water and other essential resources, primary productivity and habitat heterogeneity (Hawkins *et al*., 2003). Wetlands in areas of high rainfall and warm climates of African ecosystems are characterized by high diversities of large mammals (Finlayson and Moser, 1991). The DhWNP is also characterized with such weather conditions of high rainfall and warm climate and therefore the relatively high mammal diversity could have been a function of high rainfall and warm climates. Beside this, the vast proportion of the Park (80%) is characterized by wetland habitats revealing excess water availability throughout the year. The interaction between water and energy, through plant productivity provides a strong explanation for globally extensive animal diversity gradients. Water variables usually represent the strongest predictors in the tropics, subtropics and warm temperate zones (Hawkins *et al*., 2003). The increasing richness of plants and vertebrates toward the equator is related primarily to the tropical conditions changing throughout the year and water availability (Qian, 2009). The larger proportion of habitats in Dhati ecosystem is in permanent swamp, seasonally inundated grassland and riveriane forest having permanent water sources and moist soils for high primary productivity that would support the relatively high mammal diversity of the Park. High diversity of large mammals has been a natural feature of African savanna ecosystems (Huntley, 1982). The high diversity of large mammals in western and southern Ethiopia might be attributed to mosaic of wetland habitats (Blower, 1969; Melaku Tefera, 2011). The high diversity of large mammals in Okavango Delta, Botswana, was attributed to the high primary productivity of the floodplain habitat (Bonyongo, 2004; Kisel *et al*., 2011).

The most frequently seen large mammals in the present study area were herbivores. The high proportion of herbivores in the present study area agrees with the findings of Muchai *et al*. (2008), Girma Mengesha and Afework Bekele (2008) and Njoroge *et al*. (2009). The African savanna biome carries the earth's greatest diversity of ungulates and has sustained multispecies animal production systems for millennia (duToit and Cumming, 1999). The most evident of the biologically interesting features of African savanna ecosystems are high densities and diversities of large mammalian herbivores (Berger *et al*., 2001). Large mammal biomass varies considerably across the biome, largely in response to variations in mean annual rainfall and soil nutrient status (Bell, 1982; Hawkins *et al*., 2003; Buckley and Jetz, 2007). The high diversity of herbivores in the present study area was likely attributed to the large proportion of swamp habitats and seasonal inundated grasslands that provided sufficient grass for grazing during the dry season. Beside this, the savanna grassland interspersed by *Combertum-Terminalia* woodland burns during the dry season. This would allow regeneration of fresh grasses of high nutritive value that can support large diversity of grazers during the rainy season. Rainfall, fire and herbivory are the prime driving variables in African savanna ecosystems (duToit and Cumming, 1999). Regular burning in miombo woodland replenishes the available food for large herbivores allowing the regeneration of new vegetation during the wet season (Smith, 2011). The biomass densities of herbivores in certain protected savanna ecosystems account for some of the highest levels of herbivory (McNaughton and Georgiadis, 1986; Berger *et al*., 2001).

Despite being rarely seen, carnivores were highly diverse in the present study area constituting 35.5% of large mammal species recorded. Carnivores in Africa are more species-rich, having higher taxonomic diversity (Dalerum *et al*., 2008). African ecosystems are known to hold large diversity of sympatric carnivore species assemblage (duToit and Cumming, 1999; Mills, 2005).

Large carnivores are sensitive indicators of ecosystem integrity and they survive only where lower trophic levels remain relatively abundant (Kerr and Packer, 1997; Legendre and Legendre, 2012). The high diversity of carnivores in DhWNP is attributed to the presence of abundant and diverse herbivore species. During the present study, herbivores such as the African buffaloes, waterbuck (*K. ellipsipryminus*) and hippopotamus (*H. amphibious*) were frequently encountered aggregated into larger groups that indicated their high abundance in the area and could have potential to provide ample prey for diverse species of large carnivores in the area.

The six primate species recorded in the present survey is similar to the results of Fredrick Wanyama *et al*. (2009) from Kibale National Park. The diversity of primates in the Dhati ecosystem is attributed to extended high rainfall and the patchily distributed riverian forest between the wetland and drier woodland as well as along the many rivers flowing to the wetland of Dhati floodplain. Similarly, the high primate species richness in South America and Madagascar is directly correlated to mean annual rainfall (Burgess *et al*., 2004; Mammides *et al*., 2008). Riverine forest type is known to provide primary consumers with alternative fruit resources (Teelen, 2007; Mammides *et al*., 2008). Beside these, montane forest at high altitude areas of Gara-Arba provides suitable habitat for these forest specialist species. Habitat structure determines the reproduction and survival of primate species by providing food and reducing predation risk (Burgess *et al*., 2004; Mammides *et al*., 2008; Wanyama *et al*., 2009).

During the present study, riverine forest relatively harbored high diversity both during the wet and dry seasons. The most species-rich habitats of riverine areas provide critical corridors linking favored wildlife habitats (Mammides *et al*., 2008). Riverine areas are composed of high soil moisture and a diversity of associated vegetation that can support diverse wildlife during the

critical period of dry season (Vaugan *et al*., 2000; Kiwia, 2005). Water and pasture conditions or the combinations of both are the major factors determining the distribution of wildlife populations in their natural habitats (Balakrishinan and Easa, 1986). The high diversity of primate and carnivore species recorded from riverian forest in the present study area accounted for high diversity of large mammals. Most of the carnivore species recorded in the riverine forest during the present study revealed dense cover requirement of carnivores (Mills, 2005; Dalerum *et al*., 2008). Cover is important as large mammals depend for food sources and for protection (Girma Mengesha and Afework Bekele, 2008).

The marked seasonality and spatial variations in plant, available moisture and soil nutrients create patchiness in the quality and quantity of savanna habitats that influence the distribution of large mammal species (Bell, 1982; duToit and Cumming, 1999). The highest large mammal species in savanna grassland interspersed with *Combretum-Terminalia* woodland during the wet season in the present study area revealed the influences of flooding in wetland habitats. When flood level increases within the floodplain habitats, species concentrate on high grounds and when the flood starts receding, large terrestrial ungulates move down to the floodplain to feed on the grasses sprouting following receding flood (duToit et al., 2003; Bonyongo, 2004; Ogutu and Owen-Smith, 2005; Bennitt *et al.*, 2014). In the Okavango Delta ecosystem, the dynamics of flooding influences the community ecology of large grazers (Bonyongo, 2004; Bennitt *et al.*, 2014). The movement of large mammals from the lowland floodplain to the higher miombo areas was also reported from Kilombero Valley, Tanzania (FTSRP, 2010).

Some of the high conservation value species such as red dwarf forest buffalo (*S. caffer nanus*), Roan antelope (*H. equinus*) and Lelwel hartebeest (*A. buselaphus lelwel*) reported by local community elders during interviews were not observed in the present investigation of large

mammal diversity in DhWNP. However, beside community information, one of the previous investigator of this area (Blower, 1969) has also reported the presence of *H. equinus* and *A. buselaphus lelwel* from Wollega Province, similar area to the present study. Absence of these species in the present investigation is an indication of high environmental stress in Dhati ecosystem. High intensity of hunting by indigenous people and the sport hunting exercised in the area for the past six years might have eliminated some of the mammals reported by local people and the previous investigator. During the field work, hunting signs were observed frequently in every direction, even within 2 km of the Park-headquarters. Hunting of wildlife is a significant threat to conservation of biodiversity (Milner-Gulland and Bennett, 2003). Many species of large mammals are being constantly decreased in protected areas in Africa (Brashares *et al*., 2001; Newmark, 2008) often due to illegal harvesting for meat and trophy (Milner-Gulland and Bennett, 2003). The wildlife population decline and local extirpation from West and Central Africa is attributed to such human activities (Newmark, 2008; Ogutu *et al*., 2009). Results of surveys in Udzungwa Mountains, Tanzania have also indicated extirpation of some of the large mammals from areas of high hunting intensity (Topp-Jørgensen *et al*., 2009). Apart from this, shifting cultivation and settlements observed during the field work showed the destruction of more than 90% of the previously extended *Combertum-Terminalia* woodland habitats, which also could be accountable for the absence of these species during the present field work. Habitat loss currently emerged as most severe threat to wildlife conservation (Milner-Gulland and Bennett, 2003; Topp-Jørgensen *et al*., 2009). For example, Roan antelope (*Hippotragus equines*) is reported to be locally extinct in many areas of the ecosystem due to the loss of habitats (Sinclair and Arcese, 1995; Ogutu *et al*., 2009).

In conclusion, ecologically DhWNP contains relatively intact wetland habitat that represents a very distinct ecosystem, holding the richest habitat for the *Sudan-Gunea Biome* assemblage in the country. Despite the multi-faceted anthropogenic influence on the Park, the area hosts the globally threatened and rare species of large mammals such as Lions (*P. leo*), Orbi (*Ourebia ourebi*), Dafersa waterbuck (*K. ellipsyprimnus*), Reedbuck (*R. redunca*), Leopard (*P. pardus*), Spoted hyena (*C. crocuta*) and near threatened/conservation dependent mammal species such as African buffalo (*S. caffer*) and hippopotamus (*H. amphibious*). In addition to these, some of the high conservation value species such as *S. caffer nanus*, *H. equines* and *A. buselaphus lelwel* were reported by local community elders though not observed during flied investigation and waiting for further detailed investigation within different area gallery forests may be out of the Park boundary along the Dabus and Dilla Rivers courses. In addition to these, in unpublished preliminary report of the Mammal Research Group of the Jointed Ethio-Rassia Biodiversity Exploration indicated 18 and 17 species of small mammals and bat species, respectively, which all together would upgrade the mammal diversity of Dhati ecosystem to 66. This signifies the importance of this ecosystem and demonstrates the outstanding conservation value of DhWNP. Further detailed studies on the flora and fauna should be carried out to develop conservation actions in the area.

5.2. Population status of the African buffaloes

The high abundance of African buffaloes was recorded in DhWNP. The high abundance of large herbivores is an indication of good habitat conditions that provides ample feeding resources for such larger animals (Sinclair and Grimsdell, 1982; East, 984; Sinclair and Arcese, 1995; Kingdon, 1997; Ogutu and Owen-Smith, 2005). The population density and abundance of the African buffaloes are affected by factors such as carrying capacity, which is a function of size of

area, rainfall and food supply (Sinclair, 1977; Prins, 1996; Ogutu and Owen-Smith, 2005; Ogutu *et al*., 2012). Buffaloes require a year-round supply of grass, adequate water and shade (Sinclair, 1977). Dhati ecosystem has enough rainfall over a long period from April to November. Beside this, the area is dominated by permanent swamp and seasonally flooded wetland habitats that account for 80% of the total area and can provide sufficient green grass throughout the year. The abundance of buffaloes in the Caprivi, Namibia, was attributed to more favorable rainfall and swampy area (Coe *et al*., 1976). Rainfall affects the growth rates of buffalo populations through its direct relationship with incresed fecundity (Sinclair, 1977; Sinclair and Grimsdell, 1982; Owen- Smith, 1999).

The average density of *S. caffer* recorded in the present study area (6.17±5.38/km^2) agrees with the record of buffalo density in Serengeti National Park (6.8/km^2), Masai Mara ecosystem (7.0/km^2) and Lake Kariba in Zimbabwe (7.4/km^2) (Sinclair, 1977; Taylor, 1989; Jolles, 2007). Compared to population density of savanna buffaloes in African reserves like Ngorongoro National Park (0.2/km^2), Tswalu Reserve, South Africa (0.15/km²) and Kruger National Park (0.6/km^2), Chebera Churchura National Park, Ethiopia (2.15) (Sinclair, 1977; Cromhout, 2007; Aberham *et al.*, 2012; Njovu, 2013), the present result showed significantly high density of buffaloes in the present study area. However, compared to Lake Albert (13.9/km^2) and Lake Manyara (16.5/km^2) ecosystems (Delany and Happold, 1979; Prins, 1996; Metzger *et al*., 2010), it showed relatively low value. Buffalo population density varies from region to region depending on the length of the growing season, which ultimately depends on rainfall (Sinclair, 1977; Skinner and Chimimba, 2005). Buffalo density in East Africa is correlated positively with rainfall, and therefore with availability of food (Sinclair, 1977; East, 1984; Prins, 1996; Taolo, 2003; Turner *et al*., 2005; Skinner and Chimimba, 2005). The high density of buffaloes in the

present study was attributed to high intensity of rainfall over long period and the high proportion of swamps in this ecosystem that provide sufficient green grass during the critical period of the dry season. Taylor (1989) attributed the higher buffalo density (8 buffalo km^{-2}) from Lake Kariba in Zimbabwe to the high abundance of grass on the shores of Lake Kariba. Sinclair (1974) tabulated crude buffalo densities in different protected areas in eastern and southern Africa and found a strong correlation between density and rainfall, and developed a regression line (-8.54 + 0.017 x Rainfall) which enabled reasonable predictions of high buffalo densities over a range of rainfall from 500 to 2,000 mm. According to this equation, the density of buffalo recorded in Dhati ecosystem is well below the carrying capacity of the area.

The absence of difference in buffalo abundance between seasons in DhWNP contradicts with the result of Aberham *et al.* (2012) who obtained high buffalo population abundance during the wet season compared to the dry season. The insignificantly higher number of *S. caffer* during the dry season in this study is attributed to the high density of animals concentrated in swampy areas of the Park during the critical season as swampy habitats pertain growth of green grass to which buffaloes are attracted during the dry season. Further, the tall and thick savanna grass during the wet season in the present study area might restrict sighting of all members of the herd while counting. During the dry season, there is high visibility of game viewing for tourists (Prins, 1996; Ryan *et al*., 2006; Aremu and Obasogie, 2011), while during the wet season, the vegetation is usually overgrown and results in poor visibility of wild animals (Aremu and Onadeko, 2008).

The African buffalo population in Dhati ecosystem has shown a positive growth rate (11.7%) during 2013 and 2014. Most of the growth rates reported for *S. caffer* ranged between 6-18% (Grimsdell, 1969; Taylor, 1989; Bothma, 2002a, Taolo, 2003; duToit, 2005; Njovu, 2013). The

growth rate of buffaloes in the present study area (7.86%) is within the documented norms (Funston, 1992; Winterbach, 1999; duToit 2005; Cromhout, 2007). Similarly, Sinclair (1977) observed 11.6% in Serengeti National Park and Funston (1992) observed a 12% growth rate in the Sabi Sand Private Game Reserve. Jolles (2007) recommended a growth rate of 11.2% in Hluhluwe-Umfolozi Park, South Africa in years when the amount of rainfall was high. The amount of rainfall below the annual average (809.5 mm) influenced a decrease in $\log^{(\lambda)}$, whereas the amount of rainfall above the threshold influenced an increase as reported from Selous-Mkumi Reserve, Tanzania (Ogutu and Owen-Smith, 2005; Njovu, 2013). The relatively high average rainfall (1350 mm) and permanent swamps that can provide sufficient green grass in the present study area could be accounted for the positive growth rate of buffaloes recorded.

A balanced age structure should be maintained in any animal population for optimal productivity (Bothma, 2002a). The unbalanced sex and age structure could affect the population growth rate (Sinclair, 1977; duToit, 2005). In large herbivore population, 30 to 40% should consist of reproductive animals (Bothma, 2002a). The ratio of the age classes in a population is an indication of its current and expected reproductive status (Dunn, 1993; Halley *et al*., 2002). The age structure of the buffalo population in the present study area was biased towards adults (52.38%). The adult age class proportion in the present study was relatively lower than recorded by Aberham *et al*. (2012) who recorded 72.06% adult age class in Chebera Churchura National Park, Ethiopia and 73% by Pienaar (1969) in Crocodile Bridge buffalo population. However, the present result agrees with 54.2% adult age class composition of African buffaloes recorded in Tswalu Reserve, South Africa (Cromhout, 2007). The higher adult age ratio in the natural population of *S. caffer* might show a trend where the population is declining (Sinclair, 1977; duToit, 2005; Njovu, 2013**)**.

The sex distribution of buffaloes in the present study area deviates significantly from parity with females outnumbering males (1:5.2) omong adults. The sex ratio of the adult age class in this study contradicts with the 1:1 sex ratio of *S. caffer* reported in East Africa by Pienaar (1969) and Sinclair (1977). However, this result agrees with the findings of Mloszewski (1983), who reported significantly higher female ratio and of Bennitt (2012), who observed significantly lower adult male: adult female ratio in breeding herds of buffalo from Okvango Delta, Botswana. There is an evidence of differential mortality between sexes due to predation (Pienaar, 1969). The difference in the sex ratio may be largely due to increase in mortality of male buffaloes due to predation (Grimsdell, 1969; Prins, 1996). After 10 years of age, males leave natal herd and distribute widely away through habitats. Hence, they suffer an increased predation pressure compared with the females of the same age class, which stay in the natal herd (Sinclair, 1977; Ryan and Jordaan, 2005; Turner *et al*., 2005). Further, male buffaloes become easy target of poachers (Muchaa and Ngamdjui, 1999; Aremu and Obasogie, 2011; Aberham *et al*., 2012). In areas where sport hunting is high, the proportion of adult males is too low in game species like the African buffaloes (Taylor, 1989). Metzger *et al*. (2010) reported that when the sport quota approaches 4% of the total population, there will be no males in the population older than six years of age. Therefore, the significantly low population of adult males in the present study might also be attributed to sport hunting exercised in the area. Intensive trophy hunting by local people which has been mojor threat to Dhati ecosystem was also targeting adult male buffaloes. Beside these, there are large predators like lion and leopard, which are reported for selective killing of more male buffaloes than females (Grimsdell, 1969; Prins, 1996).

The age ratio of the present study revealed significantly low proportion of calf age class (5.7%). This lower ratio of young: adult females indicated that there is a significant reduction in the

proportion of adult females with calves, suggesting a decrease in reproductive success of buffaloes in the Dhati ecosystem. The high proportion of females in the buffalo population of DhWNP indicated that the population could have high potential to increase in number, but low proportion of the young age class (1.00: 16.00) to total population revealed that the population is dicreasing. Calves are the most vulnerable demographic category and would have been the first to suffer mortality in stressful conditions (Bennitt, 2012). As the young ones are more vulnerable to predators, they are usually hidden under dense grasses and riverian vegetation and this might also accounte to their lower proportion (Peinaar, 1969; Prins, 1996; Aberham *et al*., 2012). Further, different stress conditions noted by Sinclair (1977) and Jolles (2004) such as habitat destruction, poaching and predation reported across the range of the species in the African continent might also have similar effects on the buffalo population in DhWNP.

Recruitment is dependent on the rate at which females reproduce and the proportion of females in the population in reproductive condition (Sinclair, 1977; Mloszewski, 1983; Estes, 1991; Bennitt, 2012). In the present study area, there was high proportion of adult females compared to others in the population. However, low ratio of calves: adult females (1: 7.72) was observed. Population will likely reflect some abiotic effects that influence demography. The lack of resources due to low rainfall years may drive prime breeding females into non-reproductive condition and result in fewer offsprings in the subsequent years (Turner *et al*., 2005; Ryan *et al*., 2006). In Kruger National Park, the rainfall below the long term average coincided with a dramatic reduction in calf sightings (Ogutu and Owen-Smith, 2005). However, as rainfall is well above the average requirement for positive growth rate of buffalo population in the present study area, this could not be accounted for less number of adult females with calf. To attain maximum recruitment in a population, there should be always sufficient adult males to breed with adult

females; an assumption which may not be satisfied in areas where sport hunting quota is too high (Taylor, 1989). In areas where sport hunting affects the male age classes, conception in old females may be reduced and could be assumed that breeding would be drastically affected (Metzger *et al*., 2010). Rainfall and related food scarcity problems were not observed in the present study area. However; sport hunting was exercised for more than six years without any scientific intervention and might be the case for lower calves recorded. In addition to sport hunting, trophy hunting by local people was also selective to adult males and may also attribute to the low calves observed. On the other hand, the extensive habitat destruction in savanna grassland interspersed with *Combretum-Terminalia* woodland habitat might also be a cause of less number of calves. Most of this habitat (90%) has been destroyed by shifting cultivation and illegal settlement extended to the Park boundary. However, during the rainy season, as the floodplains get filled by flooding, large mammals of the area inhabit the habitat, eventhough habitat destruction is stressful to wildlife.

African buffaloes are highly gregarious and form large herds of 50−500 heads comprising mainly females and juveniles (Jolles, 2004; Turner *et al*., 2005). The mean herd size of savannah buffaloes is 350 (range from 12 to >1,500 individuals) (Sinclair, 1977; Prins, 1996; Melletti *et al*., 2007; Aremu and Obasogie, 2011). The overall mean of buffalo herd size (38.50 ± 2.30) in DhWNP was significantly small compared to the mean herd size of buffaloes in the Serengeti National Park, Tanzania (350), in the Kruger National Park (225·7) and in the Montane Forests of Mount Meru, Tanzania (50) (Sinclair, 1977; White and Edward, 2000). However, compared to the mean herd size of buffaloes in Chebera Churchura National Park, Ethiopia (24.8 and 7.77 during wet and dry seasons, respectively) (Aberham *et al*., 2012), the mean herd size of *S. caffer* in Kainji Lake National Park, Nigeria (13±3.1) (Aremu and Obasogie, 2011); the herd size of

buffalo in the present study area revealed relatively high size. Herds vary in size according to the season and locality (availability of food and water) (Underwood, 1982; Prins, 1996; Winnie *et al*., 2008). Larger herds usually occur in more open areas (extensive floodplains and broad river valleys) (Aremu and Obasogie, 2011). Despite the open floodplain habitats, the lower herd size in the present study area might be attributed to high level of anthropogenic activities such as hunting and extensive habitat destruction in the area. The small herd size of African buffaloes in Kainji Lake National Park, Nigeria was attributed to lack of adequate suitable habitat in addition to intensive poaching in the area (Aremu and Obasogie, 2011).

The absence of major effect with respect to season on herd size during the present study agrees with the findings of Funston (1992) and Prins (1996). Mloszewski (1983) stated that buffalo herds in Kenya did not split up on a seasonal basis. The buffaloes in the Eastern Lowveld of South Africa maintained a stable herd structure and fragmented only during periods of drought (Funston, 1992). Fragmentation of herds of buffaloes was not seasonal, but severe drought may induce herd fragmentation (Prins, 1996). However, the present result contradicts with Taolo (2003), Sinclair (1977) and Aberham *et al*. (2012). Taolo (2003) found that buffaloes in the Chobe National Park fragmented during the dry season. Sinclair (1977) stated that buffalo herds in the Serengeti fragmented seasonally and aggregated during the wet season. The relatively insignificant high herd size of buffalo during the dry season in the present study might be due to high visibility of all herd members in open swamp grassland due to high visibility than during the wet season. During the dry season, herds keep to drainage lines and rivers but during moist seasons, the herds split into temporary, smaller herds of 50−200 animals spreading into larger plains (Aremu and Obasogie, 2011).

5.3 Habitat preference of *Syncerus caffer*

During the present study, the overall mean value comparison of the *S. caffer* distribution across the habitat types of DhWNP revealed significant differece (p = 0.000). The spatial variation in vegetation componet, available moisture and soil nutrients create patchiness in the quality and quantity of savanna habitats influencing the distribution of large mammals at the landscape level (duToit and Cumming, 1999; Zweifel-Shielly *et al*., 2009). At a broader scale, selection may operate across the landscape where aspects such as soil composition, topography and vegetation structure may influence distribution (Venter *et al*., 2003).

Highest abundance of African buffaloes was recorded in seasonally inundated grassland habitat of the present study area. The river front and the grasslands along drainage lines physiographic units characterized by marshy grasslands were selected by buffaloes mostly (Winterbach *et al*., 1999). The highest density of buffaloes was observed at the Klaserie River and Nsiri River, in Klaserie Private Nature Reserve, South Africa during both seasons (Ryan *et al*., 2006). An area of low elevation, represented largely by floodplain supported high density of buffaloes in Zambezi delta, Mozambique (Beilfuss and Davies, 1999; Poilecot and Gaidet, 2011). Elephant densities on the floodplain of the Chobe River and Zambezi River were higher than in other habitats (Vandewalle, 2003), which attributed to the dependence of elephants on regular access to surface water for drinking and use of muddy holes as well as river shores for wallowing (Owen-Smith, 1988). In the Okavango Delta, Botswana and Zambez Delta, Mozambique buffaloes selected habitats with optimal levels of forage biomass and quality within floodplain areas (Beilfuss and Davies, 1999; Boyongo, 2004; Bennitt *et al*., 2014). Habitat use behavior can be influenced by food distribution, proximity to water, competition, risk of predation and shelter from weather extremes (Sinclair, 1977; Owen-Smith, 2002; duToit *et al*., 2003). The surface

water and vegetation structures had an influence on ungulate habitat preference (Owen-Smith, 2008; Poilecot and Gaidet, 2011). Sinclair (1977) and Winterbach (1999) concluded that the optimum habitat for buffaloes was determined predominantly by the presence of good quality grass and water, followed by protection from climatic extremes and predators. Next to nutritional requirements, availability of water and protection from climatic extremes play important roles in the habitat selection of buffaloes in Kalihari Desert, Tswalu Reserve, South Africa (Cromhout, 2007). The dependency of buffaloes upon habitats close to water surface is also emphasized as major driving force behind habitat selection of buffaloes in Zaire (Mugangu *et al.*, 1995). The most important environmental parameters governing buffalo habitat selection are abundant tall sweet-grass species, ample surface water, mud baths and sufficient shrubs and trees for refugia, which are mostly associated with riverine valleys, marshlands and ecotones of broad leaf montane forests (Sinclair, 1977; Prins, 1996; Macandza *et al*., 2004; Bowers, 2006). The significantly higher number of *S. caffer* in the floodplain habitats of the present study area might be attributed to highly abundant and ever-growing green grasses in such habitats. The high density of African buffaloes concentrated in swampy habitats is due to dense growth of green grasses to which buffaloes are congregated (Prins, 1996; Ryan *et al*., 2006). Beside this, there is high visibility of animal in open grassland habitats of floodplain compared to the thick and tall savanna grassland habitats (Aremu and Obasogie, 2011), this might have attributed to high abundance of buffaloes in these habitats during the present study. During the wet season vegetation is usually overgrown and results in poor visibility of wild animals (Aremu and Onadeko, 2008). Further, the high anthropogenic activities in the savanna grassland habitats of the present study area might affect distribution pattern of buffaloes in the area. In high anthropogenic activity area, African buffaloes adapted feeding in dense cover habitats of low

quality and quantity grasses. However, the present result is against the finding of Hunter (1999) who reported higher African buffalo density in Agricultural and settlement areas compared to other land use types from Chobe National Park, Botswana. According to this author, buffalo herds showed a clear preference for human dominated habitats against intense risk of being shoted at that landscape scale (Hunter, 1999).

The result of the present study supports the hypothesis that seasonal variability helps the African buffaloes for habitat selection. Some features of a specific habitat and the requirements of large herbivores change with time and space (Ben-Shahar, 1991; Dörgeloh, 1998; Winnie *et al*., 2008; Poilecot and Gaidet, 2011). Seasonal changes include alteration in climatic conditions and phenological changes in forage availability and quality, resulting in seasonal herbivore movements between seasonal home ranges (Munthali and Banda, 1992; Owen-Smith, 2002). Seasonal changes in resource availability cause temporal changes in the profitability of a given habitat, resulting in marked seasonality of habitat selection by large herbivores (Redfern *et al*., 2003; Zweifel-Schielly *et al*., 2009). Herbivores respond to variations in forage quality and quantity at a variety of spatial and temporal scales through local/large-scale movements tracking areas of high quality forage (Peinetti *et al.*, 2002; Wang *et al*., 2002; Fryxell *et al*., 2004; Macandza *et al*., 2004). In the present study area, the seasonal habitat shift of African buffaloes was governed by flood level, plant phenology and the proportion of green grass in the swards. During the rainy season, the lower elevation habitats of the permanent swamp and seasonal inundated grasslands were totally flooded by the overflow of Dhati River and other annual rivers that flow to the floodplain habitats making those resources inaccessible to buffaloes in the Park. Therefore, the larger and medium sized mammals of the area are forced to migrate to high altitude areas of savanna grasslands interspersed by *Combretum-Terminalia* woodland. However,

during the flood season and late dry season buffaloes concentrate in floodpain habitats attracted to freshly sprouting grasses following the receding flood than stay within the sensence grasses in savanna grass lands of highland areas.

The habitat selection ratio analysis in the present study area contradicts the hypothesis that state buffaloes of the study area use the different habitat types of the Park in proportion to their occurrence at $p = 0.000$ levels. The African buffaloes selectively inhabit the savanna grassland habitats sparsely intersparsed by *Terminalia-Combretum* wood during the rainy season, while avoiding permanent swamp and seasonal inundated grassland habitats. The selection for the drier habitats of *Combretum-Terminalia* woodland interspersed in highly abundant tall savanna grasses during the rainy season coincide with increased productivity in that habitat due to the growth of annual grasses (Poilecot and Gaidet, 2011). *Combertum-Terminalia* woodland occures in dry parts of the African buffaloes range, but rainfall during the rainy season creates temporary water holes, removing the spatial constraints imposed by the daily water dependency of buffaloes. A comparison of the seasonal changes in the habitat association of the buffaloes in Chebera Churchura National Park, Ethiopia showed that the African buffalo population preferred savanna grasslands with scattered trees during the wet season (Aberham Megaze *et al*., 2012). The habitat selection for mopane woodland during the rainy season coincides with increased productivity of the habitat due to the growth of annual grasses (Bennitt *et al.*, 2014). Further, the grassland with scattered trees that had burnt during the dry season has lush green swards during the wet season (Conneely, 2003; Bowers, 2006; Poilecot and Gaidet, 2011). The investigation of buffalo high elevation area habitat preference during the rainy season in Chebera Churchura National Park, Ethiopia, Okvango Delta Floodpain, Botswana and Zambezy Delta, Mozambique,

has been attributed to overflow of rivers and attraction by highly nutritious annual grasses (Poilecot and Gaidet, 2011; Aberham Megaze *et al*., 2012; Bennitt *et al*., 2014).

During the flood season, the seasonally flooded grassland habitat was significantly selected, while most of the permanent swamp habitats were inaccessible due to flood and so only utilized at intermediate level. However, the drier part of the Park, dominated by savanna grassland was avoided. During this season, the grass composition of the dry habitat areas becomes mature and could not provide quality forage for buffaloes and therefore, the herds moved down to seasonally inundated grassland habitats following the receding flood to graze on newly flourishing grasses. The significant selection of African buffaloes to seasonally flooding grassland habitats during flood season was also reported from Okvango Delta and Zambezy Valley floodplain habitats (Beilfuss and Davies, 1999; Poilecot and Gaidet, 2011; Bennitt *et al*., 2014). Prins (1996) reported the importance of the floodplains in providing green forage during the dry season in the Lake Manyara National Park, Tanzania. The evergreen perennial sedges and grasses of floodplain habitats provide enough forage for bulk feeding African buffaloes (Conneely, 2003; Bowers, 2006; Poilecot and Gaidet, 2011).

During the late dry season, the buffaloes showed significant preference to permanent swamp habitat dominated by *Thypha-Cyperus* grass and sedge vegetation as reported earlier by Ryan *et al*. (2006). During this period, the receding flood water caused grasses in the permanent swamp habitat to be most productive (Zhang *et al*., 2005; Murray-Hudson *et al*., 2006). The contrast between the profitability of secondary and tertiary floodplains and the drier savanna grassland resulted from strict differences of forage resources in quality and difference in accessibility of those habitats (Winnie *et al*., 2008). The floodplain habitats, which appeared to be acting as resource buffers during the most limiting season provide access to relatively high quality forage

in heterogeneously distributed patches (Murray-Hudson *et al*., 2006; Owen-Smith and Cain, 2007). When the water dried up from most habitats, buffaloes narrowed their selection range to permanent swamp habitats in the floodplain (Ryan, 2006; Poilecot and Gaidet, 2011). The most crucial habitat for any herbivore is the one used during the most unfavorable season (Sinclair, 1977). In the present study, this is the late dry season when the marsh grasslands were specifically selected for grazing by *Syncerus caffer* population. During this season, the concentration of buffalo herds in swampy habitats along the Dhati River dominated by *Thypha-Cyperus* grass intersparsed by nutritios grasses such as *Leersia hexandra* and *Cynodon dactylon*. In the Kruger ecosystem, the optimum habitat for buffalo herds during the dry season is the riverine vegetation dominated by reed beds along the Klaserie River and Nassir River (Ryan, 2006). Qualitative and quantitative description in Okovango Delta suggests that when other areas of the vegetation were already yellowish, greyish or brownish, the floodplain and river sides were still greenish and support high density of large mammals (Bonyongo and Harris, 2007). Greenness of grass was the main determinant factor of habitat utilization by large grazing ungulates during the dry season (Traill and Bigalke, 2006; Poilecot and Gaidet, 2011). The quantitative measures of green grass across the different habitat types during the late dry season in the present study area, showed significantly higher proportion of vegetation greenness from permanent swamp habitats during this period. Further, the only large surface water for drinking and wallowing signifies the contribution of surface water for the selection of the habitat.

In the present study, the riverine woodland habitat used by African buffaloes at intermidiet level during all seasons being a buffer zone between floodplain habitats and high altitude area savanna grassland which were used during contrasting seasons. Toward the end of rainy season this habitat was selectively used as grasses of savanna grassland habitat matured, but floodpain areas

were inaccessible due to high flood level. Similarly, at the beginning of rainy season such habitat serves as refugia for buffalo herds migrating to highland habitats. Bennit (2012) also reported similar result to this study from Okovango Delta Floodplain, Botswana. Similarly, Prins (1996) reported seasonal buffering value of this ecotonal habitat for African buffaloes migrating between seasonal home ranges in Lake Manyara National Park, Tanzania. During the present study bamboo woodland habitat was ignored during most of the study period. This might be attributed to lower grass biomass in this habitat (personal observation).

The regression analysis of relative abundance of African buffaloes with elevation has revealed that buffaloes prefer high altitude area habitats during the rain season. However, relative abundance of the population of buffaloes was negatively correlated with elevation both during the flood season and the late dry season. The significant difference in the distribution of African buffaloes across the altitudinal gradient in DhWNP is consistent with most of the previous studies elsewhere in Africa (Sinclair, 1977; Scoones, 1995; Prins, 1996; Scholes *et al.*, 2003; Macandza *et al*., 2004; Bowers, 2006; Bennitt *et al*., 2014). Topography affects grass quality through its influence on the distribution of nutrients. Nutrients together with water move down a slope gradient and accumulate in lowland areas that promote the growth of abundant green foliage (McNaughton *et al*., 1985; Scoones, 1995; Scholes *et al.*, 2003). Low elevation areas, represented largely by floodplain were important during the flood and dry season supporting high density of buffaloes in Zambezy Valley, Mozambique (Beilfuss and Davies, 1999; Macandza *et al*., 2004; Poilecot and Gaidet, 2011). African buffaloes show a preference for midslopes and lowlands during the dry season (Prins, 1996; Winterbach, 1999; Bowers, 2006; Macandza, 2009). Funston *et al*. (1994) suggested a number of reasons for this, including lower predation risk (due to improved visibility), the availability of high biomass of favored forage

species and the presence of water. Buffaloes are highly water dependant (Skinner and Smithers, 1990) and the proximity of water helped to explain the buffalo moving to the lowlands in the Kruger National Park (Bowers, 2006; Poilecot and Gaidet, 2011; Macandza, 2009). The higher altitude preference of buffaloes during the rainy season in the present study area is supported by studies elsewhere (Sinclair, 1977; Scoones, 1995; Prins, 1996; Ryan, 2006; Bowers, 2006; Bennitt, 2012). The investigation of buffaloes preference to high altitude during rainy season in Chebera Churchura National Park, Ethiopia and Zambezy Delta, Mozambique attributed to overflow of rivers in the floodplain areas (Beilfuss and Davies, 1999; Aberham Megaze *et al*., 2012). The habitat selection for mopane woodland during the rainy season coincided with increased productivity in that habitat due to the growth of annual grasses (Bennitt *et al*., 2014). Further, the grassland habitat with scattered trees burned during the dry season has lush green swards of higher nutritive value during the wet season (Bowers, 2006; Poilecot and Gaidet, 2011; Aberham Megaze *et al*., 2012).

The correlation of buffaloes abundance to proportion of green leaves within the different habitat types revealed that habitat section of the species is positively affected by proportion of green leaves in the late dry season. Greenness of grass was the main determining feature in the habitat utilization of large grazing ungulates at Malilangwe, Zimbabwe with all species associating with a relatively greener grass sward (Traill and Bigalke, 2006). In earlier studies, Sinclair (1977) pointed out that the drying out of grass makes them less palatable, and this becomes the main driving force for the migration to moist areas containing denser patches of green grass in lowland areas. Valley bottoms have a greater accumulation of heavy clay soils and are vegetated by deeper rooted plant species that retain high proportion of green grass long into late dry season (Morison *et al*. 1984). Clay soils that are characterized with good soil moisture retain ample

green grasses supporting high herbivore population during the dry season (Sinclair, 1977; Ryan, 2006; Macandza, 2009). In conclusion seasonal fluctuation of grass quality, flood level, altitude, proportion of green grass within habitats and anthropogenic activities in the area affected habitat preference of African buffaloes in DhWNP.

5.4 Feeding behavior of *Syncerus caffer*

Direct observation as well as back-tracking assessments in the feeding sites of African buffaloes during different seasons revealed that 45 plant species were foraged by *S. caffer* in DhWNP. Among these, 30 species were of Poacae family, while browse species constituted 14 species. The grass species recorded as forage resources from DhWNP are mentioned as major forage species of both domestic and wild herbivores in East Africa (Pratt and Gwynne, 1977). Most of the dietary componentes of *S. caffer* recoreded from the present study site were also reported as dietary components of African buffaloes across the range of the species (Field, 1976; Sinclair, 1977; Prins, 1996; Macandza *et al*., 2004; Bowers, 2006; Aremu and Onadeko, 2008). Among the dietary species recorded in the present study, *Chloris gayana*, *Cynodon dactylon*, *Paicum maximjm*, *Sporobolus* sp. and *Hyparrhenia filipendula* were also reported from Serngetti National Park (Sinclair, 1977) and Lake Manyara National Park (Prins, 1996), East Africa. Pienaar (1969) from Kruger National Park, South Africa identified *Panicum coloratum, Digitaria* sp., and *Panicum maximum* to be abundant in the diet of *S. caffer*. The *Andropogon pseudapricus*, which was amog the principal forage species durig the rainy season was described as a major contributing grass species of African buffaloes in Kainji Lake National Park, Nigeria (Aremu and Onadeko, 2008). *Cynodon dactylon* and *Panicum* species were described as important forage resource of *S. caffer* during both seasons in Great Fish River Reserve, South Africa (Tshabalala, 2008). In addition to these, forage species such as *P. maximum* and

Hyparrhenia sp. are also reported as major dietary components of Sable antelope (*Hippotragus niger*) in Pretorius Kop Region of Kruger National Park (Parrini, 2006, Magome *et al.*, 2008). High grass biomass species such as *P. maximum* and *Hyperrhenia* sp. are principal diet of bulk grazers (Prins, 1996; Landman and Kerley, 2001; Macandza *et al.*, 2004; Owen-Smith, 2008).

The dietary composition of *S. caffer* recorded in DhWNP varied with season as buffaloes feeding sites changed with season, grazing in different plant communities that differ in its grass species composition and abundance. Some features of a specific habitat and the requirements of herbivores change with time and space (Ben-Shahar, 1991; Dörgeloh, 1998). Herbivores respond to coarser-scale, spatial and temporal variation in food quality and quantity through local short-term shifts in foraging locations (Sinclair, 1977; Fryxell *et al*., 2004; Ogutu and Owen- Smith, 2005; Ryan *et al*., 2007). During the present study, variation in habitat quality and accessibility with seasons primarily influenced the dietary components of *S. caffer* population in the Dhati ecosystem. During the rainy season, the expanding flood drives buffaloes to high altitude areas of savanna grassland interspersed with *Terminalia-Combretum* woodland habitat, while during the flood season, buffaloes move down to the catena attracted by the freshly sprouting grasses following the receding flood in seasonally flooded open grassland habitat. Thus, feeding and ranging behaviors of buffaloes are subject to constraints such as the flood level and grass species phenology. In earlier studies, seasonal changes in the vegetation quality and water availability have been shown to alter both ranging and feeding habits of buffaloes (Funston *et al.*, 1994; Bonyongo and Harris, 2007; Bennitt *et al*., 2014). Taylor (1989) and Taolo (2003) attributed the floodplain use of buffaloes to quality of fresh grass in Lake Kariba and Chobe National Park, respectively.

The forage component selection analysis of *S. caffer* on the basis of forage ratio revealed that the utlization of grass species such as *Andropogon* sp., *Hyparrhenia* sp., *Panicum maximum*, *Sporobolus* sp., *Chloris gayana* and *Pennisetum* sp. did not significantly differ during the rainy season. However, the African buffaloes were significantly selective to grass species such as *Panicum maximum*, *Hyparrhenia* sp. and *Cynodon dactylon* during the flood season. During the late dry season *Cynodon dactylon*, *Echinochloa pyramidalis* and *Leersia hexandra* were preferably grazed by the study species. The present result of the feeding behavior of *S. caffer* recorded in DhWNP agrees with the result of feeding tactics of buffaloes described by Beekman and Prins (1989) from Lake Manyara National Park in East Africa. They described that African buffaloes are bulk feeders when the food is both abundant and of higher quality as well as when food is abundant but of poor quality. However, the species displays selective feeding behavior when the food is abundant, but of mixed quality (Beekman and Prins, 1989). In Dhati ecosystem, ample forage resources of high quality were available during the rainy season in the savanna woodland, following massive fire burn in this habitat. During the rainy season, forage ratio was not significant, indicating that buffaloes used different grass species in proportion to their availability. This low selection level was probably linked to the abundant and high quality forage prevalent across the landscape in the rainy season, reducing the benefit of selective foraging (Manly *et al*., 2002; Macandza *et al*., 2004; Owen-Smith, 2008). Both leaf production and crude protein concentration are highest during the rainy period providing high quality forage to African buffaloes (Prins and Beekman, 1989; Bowers, 2006; Macandza, 2009). The habitat selection for highland habitats of mopane woodland in Okvango Delta, Botswana, Zambezi Delta, Mozambique and Kilombero Valley, Tanzania during the rainy season is attributed to high quality annual grasses (Beilfuss and Davies, 1999; FTSRP, 2010; Bennitt *et al*., 2014).

The significant selection of *Panicum maximum*, *Hyparrhenia* sp., and *Cynodon dactylon* sprouting in seasonally flooded habitats by buffaloes during the flood season is attributed to their high nutritive value compared to the grass species in the savanna grassland interspersed by *Combretum-Terminalia* woodland that mature and drastically decrease in quality. This result is consistent with published data of Mahala *et al*. (2009), who suggest that the quality of grass species decline with increasing age. In savanna ecosystems, as the season progresses, available graze lignifies and becomes unpalatable to a point where even a bulk grazer becomes selective (Macandza *et al*., 2004; Winnie *et al*., 2008). However, forage resources of high quality in seasonally flooded open grassland habitat were freshly sprouting following receding flood. Similarly, the selective use of floodplain grass resources by *S. caffer* owing to their high nutritive value was reported in earlier studies from Lake Manyara National Park and Kilombero Valley, Tanzania (Prins, 1996; Beilfuss and Davies, 1999), Satara region of Kruger National Park, South Africa (Macandza *et al*., 2004) and Okvango Delta Floodplain, Botswana (Bonyongo and Harris, 2007; Bennitt *et al*., 2014).

The significantly selective feeding behavior of *S. caffer* during the late dry season is attributed to mixed quality forage resources in seasonally inundated open grassland and permanent habitats. During this period, most of the grass species, both in savanna grassland and seasonally flooded habitats, dry up and buffaloes feeding range was restricted to narrow ranges of the permanent swamp habitats. During this period, buffaloes selectively forage on grass species possessing higher proportion of green leaves such as *Leersia hexandra*, *Cynodon dactylon* and *Echinochloa pyramidalis* dominating the permanent swamp habitats. This finding agrees with most of the studies conducted across the range of *S. caffer* in the past (Morison *et al*., 1984; Prins 1996; Redfern *et al.* 2003; Murray-Hudson *et al*., 2006; Macandza ,2009; Bennitt, 2012). The strong

dependence of buffaloes on secondary floodplains appeared to be acting as resource buffers during the most limiting season by providing access to relatively high quality forage (Murray-Hudson *et al*., 2006; Owen-Smith, 2008). Prins (1996) and Bowers (2006) reported the importance of the floodplains in providing green forage during the late dry season in Lake Manyara, National Park and Satara, in Kruger National Park, respectively. Therefore, the significantly high selective grazing of *S. caffer* during the late dry season in the present study is attributed to the limited green forage in seasonally flooded grassland and savanna grassland habitats compared to permanent swamp habitats. Lowlands of high clay soils that have a good soil moisture retention capacity enable grasses to retain their greenness (Macandza, 2009). Additionally, Redfern *et al.* (2003) have shown empirically that buffaloes select areas close to water sources in Kruger National Park. The large biomass herbivores, like African buffaloes prefere for lowland habitats during the dry season (Prins, 1996; Winterbach, 1999; Bowers, 2006; Macandza, 2009). Funston *et al*. (1994) suggested that the availability of high biomass of forage species and the presence of water attract buffaloes to lowland habitats. In earlier studies, Sinclair (1977) and Leuthold (1972) pointed out that the drying out of grass, making them less palatable, was the main drivig force for the migration to moist areas of lowland containing dense green grasses. Therefore, such higher quality of resources limited to permenant swamp habitats lead to selective feeding behavior of the buffaloes in DhWNP (Beekman and Prins, 1989; Macandza *et al*., 2004).

During the present study period, the forage component of African buffaloes composed significantly higher number of grass and browse species during the late dry season. This might be related to the scarcity and poor quality of the preferred grass species in sward. The increase in dietary breadth of large herbivores during the late dry season was reported across the range of the

African buffaloes in the past (Sinclair, 1977; Prins 1996; Owen-Smith, 2002; Macandza *et al*., 2004). During the long dry season, most grass species stop leaf production and possess very minimal green forage to grazers. During such scarcity periods, buffaloes are adapted to incorporate more grass species in the diet as well as depending up on those species neglected earlier (Macandza *et al*., 2004). Foraging theory predicts that diet should be widened as food availability decline (Owen-Smith, 2002). Similar to this theory, the dietary breadth of *S. caffer* was observed to increase in number of browse and grass species in the present study site during the late dry season of scarcity period. The grass species such as *Echinochloa pyramidalis*, *Pennisetum* sp. and *Leersia hexandra* became among the significantly contributing forage species of buffaloes during this period. During harsh conditions, when the abundance of quality grass decline below sub-minimal level of crude protein, buffaloes consume more browse species owing to their superior protein content (Sinclair, 1977; Stark, 1986; Winterbach, 1999; Bowers, 2006). African buffaloes widen their dietary components during the dry season limited by forage quality (Prins, 1996; Bowers, 2006; Macandza, 2009). Similarly, during the present study period the grass species such as *Echinochloa pyramidalis* and *Pennisetum* sp became among the principal forage of buffaloes, however, grass species such as *Typha* sp. and sedge of *Scleria* sp. remain ignored.

The avoidance of *Cymbopogon* sp. and *Setaria incrassata* in the present study area might be attributed to the unpalatable nature of such grass species to the African buffaloes, as noted earlier (Futnston *et al*., 1994; Perrin and Brereton-Stiles, 1999). Similarly, Macandza *et al.* (2004) reported that *Setaria* species were avoided by the buffaloes in the Kruger National Park. Field (1976) attributed *Cymbopogon* sp. avoidance by African buffaloes due to its aromatic smell owning to high oil content. However; the present result contrasts the finding of Tshabala (2008),

who reported *Setaria* sp. as principal diet of buffaloes during the dry season which he attributed to the scarcity of grass species in his study area in Kalahari Desert, Tswalu Reserve, South Africa.

Statistical analysis of the dietary contribution of the most widely distributed grass species across in the present study revealed that their contribution in the diet of *S. caffer* significantly vary through seasons. *Panicum maximum* and *Hyparrhenia* sp. were among the major forage resources both durig the rainy and flood seasons. However, their contribution significantly decreased during the late dry season. This result support the results of Perrin and Brereton-Stiles (1999) and of Macandza (2009), who have recorded higher dietary contribution of *P. maximum* at the beginning of the dry season from eastern and southern Africa, respectively, which they attributed to its decrease in abundance and retaining lower proportion of green leaves during the late dry season. Similarly, in the present study area, *P. maximum* dominantly occured in seasonally inundated grassland habitat where its contribution rank was first during the flood season. But, as this habitat got dried up during the late dry season, the species was left with very minimal proportion of green leaves accounting to the relatively low acceptance by African buffaloes. The contribution of *Hyparrhenia* sp. to diet of buffaloes significantly decreased during the late dry season owning to its senesce. The *Hyparrhenia* sp. are mostly grazed while young, but become rough and unpalatable as they mature (Mahala *et al*., 2009). However, *Leersia hexandra* and *Echinochloa pyramidalis* were selected significantly only during the late dry season in DhWNP owning to their high proportion of green leaves; a determinant factor in late dry season for which the two species qualified. The diet of buffaloes changed markedly through the season in terms of species selected as well as contribution (Owen-Smith, 2002). Macandza (2009) attributed such differences in the contribution of grass to diet of buffaloes across seasons

to shifting in grazing locations in terms of plant community and landscape position in Kruger National Park, South Africa. In Okvango Delta, Botswana, the floodpain habitats dominated by *L. hexandra* and *C. dactylon* were frequently grazed by large herbivores during the late dry season (Bonyongo, 2004; Bennitti *et al*., 2014).

During the present study, grass species such as *Chloris gayana* and *Sporobolus* sp. contributed minimal share to the diet of African buffaloes in every season. However, their contribution has significantly increased during the late dry season. The lower dietary contribution of these grass species might be due to their relatively short height as utilization of short grasses might be neglected owning to their inadequate bite size to large herbivores (Owen-Smith, 2002). Similar to the present study, Conneely (2003) also reported lower contribution of short grass species such as *Digitaria erianta, Eriagrost rigidior* and *Sporobolus pappophoroides* to the diet of African buffalo population in Gorongosa National Park, Mozambique. However, *Cynodon dactylon*, with similar average height with *Chloris gayana* and *Sporobolus* sp. were preferably accepted both during flood season and late dry season in the present study area. So, the issue of height alone could not be a sufficient reason for their low contribution in the diet of buffaloes. Beside their short hight, the two species were also relatively low in abundance in DhWNP. The less inclusion of *Panicum stapfianum* in the diet of buffaloes was attributed to the lower availability of the species in the study site, in Kruger National Park, South Africa (Landman and Kerley, 2001).

The strong correlation of grass species utilization with the abundance of the preferred grass species in the present study site agrees with the result of previous authors (Beekman and Prins, 1989; Owen-Smith and Cumming, 1993; Conneely, 2003; Macandza *et al*., 2004; Bowers, 2006). Available grass phytomass is an essential forage requirement for a bulk-feeder like *S. caffer*

(Bowers, 2006). The forage preference study from Kruger National Park revealed that buffaloes forage selection is determined by the local abundance of preferred grass species (Macandza *et al*., 2004). Owen-Smith (1999) reported that animals select their diets on the basis of forage availability and quality. In the Okavango Delta, buffaloes select habitats with optimal levels of forage biomass and quality (Bennitt, 2012). Owning to their body size and gut morphology, African buffaloes are known as supreme bulk grazers, implying that their feeding strategy is to maximize biomass intake (Owen-Smith and Cumming, 1993). However, though a bulk grazer, African buffaloes are protein limited in their foraging (Sinclair, 1977) and therefore, they require abundant high quality grass (Beekman and Prins, 1989). During the present study, the most preferred grass species such as *Hyparnia* sp., *Panicum maximum*, *Cynodon dactylon* and *Leersia hexandra* were also more abundant than other less palatable grasses within the feeding sites of buffaloes.

The average sward heights of the preferred grass species in Dhati ecosystem proved that *S. caffer* preferred medium height grass species than tall and low hieght varieties. Grass species in tall height class such as *Cymbopogon* sp. and *Setaria* sp. were mostly ignored during this study period. Beside this, short height grasses such as *Chloris* sp. and *Sporobolus* were consumed only at intermediate level. The present finding agrees with that of Perrin and Brereton-Stiles (1999), who reported that the African buffaloes prefer medium to tall grass species. However, *Pennisetum* sp. with similar height to *Cymbopogon* sp. was accepted at intermediate level during the rainy and flood seasos and significantly selected during the late dry season reducing the absoluteness of height to determine grass species selection by African buffaloes. Owen-Smith (1999) reported that animals select their diet species on the basis of forage availability and quality.

The grazing frequency of grass species was negatively correlated (R^2 = -0.673) with number of stems within the grass tuft. Other studies have found the stem to leaf ratio to be an important selection criterion in forage selection by buffaloes (Mugangu *et al*., 1995; O'Reagain and Owen-Smith, 1996; Magome *et al.*, 2008). As grass species and grass parts differ markedly in their nutrient contents (McNaughton and Georgiadis, 1986), buffaloes select relatively nutritious grass species and parts in order to maximize intake of proteins and carbohydrates (Sinclair, 1977). Stems contain considerably higher levels of structural carbohydrates compared to leaves (Prins, 1996; Bowers, 2006; Bennit, 2012). Earlier studies on sable foraging behavior have also indicated a preference for green leaves and avoidance of stems (Parrini, 2006). African buffaloes exhibited a preference for species with a high leaf to stem ratio, as higher proportion of leaf used as indicator of higher crude protein content (Owen-Smith and Novellie, 1982). During the present study, grass species such as *Panicum maximum*, *Hyparrhenia* sp., *Cynodon dactylon* and *Leersia hexandra* have highly contributed to diet of buffaloes. However, *Pennisetum* sp. and *Andropogon* sp. which were utilized by *S. caffer* at intermidiet levels possessed many stems. These might revealed multiple interactive effect of grass physical-chemical features as well as grass availability and herbivory to effect feeding behavior of buffaloes.

Grass species acceptance was significantly positively correlated (R^2 = 0.935) to the proportion of green leaves. Field (1976) found a positive relationship between the preference of buffaloes and the proportion of green leaves of the preferred grass species available in the area. Greenness of grass was the main determinant feature in the habitat utilization of large grazing ungulates at Malilangwe, Zimbabwe with all species associating with a relatively greener grass sward (Traill and Bigalke, 2006). A senescent, highly lignified sward is a poor food source for ungulates, and such plants are likely neglected by ungulates (Sinclair, 1975). During the present study, the

consumption of *P. maximum* and *Hyparrhenia* sp., the principal forage species both during the rainy and flood seasons was significantly reduced ($p = 0.000$) during the late dry season owning to drying up of seasonally flooded habitat where these species were dominant. However, the contribution of the greener grasses such as *Leersia hexandra, Echinochloa pyramidalis* and *Sporobolus* sp. were significantly increased in the food of buffaloes owning to their higher proportion of green leaves (Prins, 1996; Bowers, 2006; Macandza *et al.*, 2004) .

During the present study, positive correlation was found between mean acceptance frequency and mean percentage of leaf crude protein content of grass species ($R^2 = 0.500$). The most nutritious grass species such as *P. maximum, Cynodon dactylon, Leersia hexandra* and *Hyparrhenia* sp. were mostly preferred, while the less nutritious grasses such as *Setaria incrassata*, *Cymbopogon* sp. and *Echinochloa pyramidalis* were ignored by *S. caffer* population in DhWNP during most of the study period, except during the late dry season when *Echinochloa pyramidalis* became among the principal food item of buffaloes. Most previous studies have also shown that crude protein is a deciding factor in forage selection of ungulates (Field, 1976; O'Reagain and Owen-Smith, 1996.). Similarly, variation in the quality has been demonstrated to influence the resource selection of African buffaloes (Sinclair and McGwynne, 1972; Sinclair, 1977; Mugangu *et al*., 1995; Prins, 1996; Macandza *et al*., 2004; Winnie *et al*., 2008). Field (1976) observed that selective grazing enables buffaloes to consume a diet of significantly higher nutritive value than that of the average sward. Sinclair and Gwynne (1972) examined the rumen contents of buffaloes in the Serengeti during different times of the year, to determine the behavioral selection of grass species and found that buffaloes exhibit a preference for species with a high nutrient quality.

Young leaf was the most preferred part of grasses during all the three seasons ($p < 0.000$) compared to matured leaf. Mature leaves were less preferred by *S. caffer* population due to the fact that they are dry and coarse thereby hindering digestibility (Holechek, 1994; Aremu and Onadeko, 2008). As a plant matures, it gradually accumulates structural tissues, which would impose digestion constraints. On the other hand, young leaves are more palatable, succulent and easy to digest making the feed nutrients easily available to the animal for growth and to maintain reproductive process (Mugangu *et al*., 1995; Prins, 1996; Aremu, 2001). Forage digestibility is expected to depend on plant phenology and an animal should adjust its foraging behavior in accordance with the temporal changes in plant phenology (Fryxell *et al*., 2004; Macandza *et al*., 2004; Winnie *et al*., 2008; Treydte *et al*., 2013). Overall, the primary concern of selection of grass species by grazing herbivores was determined by grass nutrient content, palatability, abundance and greenness (Prins, 1996; Bowers, 2006; Treydte *et al*., 2013).

In conclusion, the forage component of African buffaloes vary with season as the population change their feeding location governed by flood levels, maturity of grass species and grass physical and chemical attributes. In the rainy season, the lowland areas occupied by floodplain was submerged with water and buffaloes migrated to the highland areas of *Terminalia-Combretum* habitat dominated by grass species such as *Hyparrhenia* sp., *Andropogon* sp., *Pennisetum* sp., and *Cymbopogon* sp. However, *P. maximum*, *Hyparrhenia* sp. and *C. dactylon* that dominated seasonally flooded lowland habitat were utilized by buffaloes starting from the end of the rainy season, following the receding floods, while the lowest altitudal areas of the permanent swamp habitats dominated by *Leersia hexandra*, *Echinochloa pyramidalis* and *Cynodon dactylon* were frequently grazed during the late dry season (February-May). Therefore, as such habitats were varying in their grass species composition; the dietary components of

buffaloes also varried with season. The relatively more nutritious grass species within the feeding quadrats were also more abundant indicating that buffaloes preferably graze in areas of more abundant high quality grass species. Further, the proportion of green leaves of the preferred species and their leaf production seems to affect frequency of utilization of those species by *S. caffer*. The more nutritious grass species that produced sufficient leaves such as *P. maximum, Cynodon dactylon, Leersia hexandra* and *Hyparrhenia* sp. were mostly preferably consumed by the study species in DhWNP and became principal dietary components of *S. caffer* population. While during the rainy season and flood season, most of the grass species described as major forage resources of the African buffaloes provided sufficient crude protein required for growth and maintainance, only *Cynodon dactylon, Leersia hexandra* and *Chloris gayana* could provide a minimum crude protein requirement for buffaloes for maintenance long into the late dry season.

5.5 Anthropogenic impacts

Data on anthropogenic activities in DhWNP collected during the present investigation have revealed that the Park is under intense human influence due to habitat destruction, hunting and overgrazing by domestic cattle. Though the area remained a wilderness until 2005, the Government of Oromia Region resettled farmers from East Hararge Zone in Kellam Wollega Zone of the study area, following prolonged drought. Since then, the extensively large woodland of Dhati ecosystem was inhabited by community exercising shifting cultivation in the *Combetum-Terminalia* woodland. Currently, what remains is the border of seasonal inundated grassland. Though the Park boundary was demarcated, Woreda officers around the Park did not cooperate for its implementation; rather they competed with each other to own some parts of the Park under their Woreda's territory. During the field work, extended villages were observed in

the northwest direction between wetland and Gara-Arba forest and the east close to the boundary of the wetland and the woodland restricting the seasonal movements of large mammals. Seasonal migration of large mammals from the floodplain during the rainy season into the adjacent *Combretum-Terminalia* woodland and forests of Gara-Arba area was an integral part of the Dhati ecosystem as the wetland was fully flooded during the rainy season. Any major disruption in the route, timing or duration of migratory movements of large mammals may have direct threats for the survival of such migratory species (Bonyongo, 2004). Such sudden anthropogenic impacts on the area can be accounted for extirpation of some mammals reported by indigenous community during the present investigation. Habitat loss is a severe threat to biodiversity conservation (Naeem *et al.*, 1999; Brooks *et al*., 2002; Smith and Smith, 2003). For example, Roan antelope (*Hippotragus equines*) is reported to be locally extinct in many areas of the ecosystem due to disruption and loss of its habitat (Campbell and Borner, 1995; Sinclair *et al*., 2002). In Africa loss of wildlife habitats is a widespread phenomenon (Balakrishnan, 1994; Newmark and Hough, 2000). In the Serengeti ecosystem, there have been marked decline in the population of black rhino (*Diceros bicornis*), elephant (*L. africana*) and African buffalo (*S. caffer*) inside the protected area (Metzger *et al*., 2010; Sinclair *et al*., 2007). Absence of these species in the present investigation is an indication of high environmental stress in Dhati ecosystem. Beside these, the intensive irrigation activities observed from upstream of Dhati ecosystem might significantly affect biodiversity of the area, particularly the water dependent species like hippopotamus. The improper water use in the upstream of floodplain areas along with global climate change can significantly impact the biodiversity (Wang *et al*., 2002; MEA, 2005). For instance, lack of surface water in dry seasons in Katavi National Park, Tanzania led to considerable hippopotamus and buffalo mortalities (Caro, 2008).

Signs of hunting were observed frequently during the field work; even within 2 km of the Park headquarter area. High intensity of hunting by indigenous people from Zones sharing the boundary of the Park as well as traveling long distance up to 600 km, and the licensed hunting exercised in the area during the past six years might be the cause for the absence of some mammals reported by local people as present in the area and the previous report (Blower, 1969). Hunting of wildlife is a significant threat to conservation of biodiversity (Milner-Gulland and Bennett, 2003). Populations of several species of large mammals are being decreased in protected areas of Africa (Brashares *et al*., 2001; Newmark, 2008) due to the illegal wildlife harvesting for meat and trophies (Milner-Gulland and Bennett, 2003). The wildlife populations in West and Central Africa have declined consistently and some of them locally extirpated due to hunting (Robinson and Bennett, 2000a; Barnet, 2000). Surveys in Udzungwa Mountains, Tanzania, also indicated the extirpation of some large mammals from areas of high hunting intensity (Topp-Jørgensen *et al*., 2009). Buffalo populations in particular are drastically affected by poaching (Sinclair, 1977; Skinner and Chimimba, 2005). Buffalo is a favorite bush meat in many parts of Africa, making it susceptible to poachers. Buffaloes are known to be targeted by illegal hunters (Sinclair, 1977; Hilborn *et al*., 2006; Keane *et al*., 2008). Analysis of the trends in the buffalo population of Kruger National Park attributed population changes primarily due to illegal hunting (Hilborn *et al*., 2006). Illegal hunting remains a major threat to conservation efforts of buffaloes in the Serengeti ecosystem (Loibooki *et al*., 2002; Holmern *et al*., 2007). Similarly, during the present study period in DhWNP, African buffaloes were special target both to bush meat hunters and trophy hunters.

The extremely high number of domestic cattle (around 10,000) grazing within the Park area might out compete the wildlife of the area. During the dry season, the pastoralists from the

surrounding six Woredas temporarily settle within the Park and use the wetland habitats of the Park until the rain season. High cattle density accompanied with climate change and variability is amplifying stresses to animals due to the limited access to key resources (Olff and Grant, 2008). Wildlife−livestock conflicts are primarily focused on access to grazing and water sources in the dry season (Daszak *et al*., 2001). Impacts of livestock management on savanna rangelands vary depending on stocking rate and its interactions with rainfall regime, soil properties and extreme drought. The heavily grazed rangelands exhibit symptoms of progressive degradation, which might be a cause of local extirpation of wildlife (Brashares *et al*., 2001). Beside this, there might be spread of infectious diseases between wildlife and domestic cattle. Mlengeya and Lyaruu (2006) have mentioned livestock to be the major carriers of diseases to the wildlife populations. During the present dry season data collection period, about 70 dead *Hippopotamus amphibious* were recorded in Park area, mostly in pool named ‘‘hippo pool’’. During the oral interview with local community of Gua-Kebe Woreda, Harer Village, the community blamed that the wildlife spread anthrax to their cattle and 20 people died of eating the meat of diseased oxen. Therefore, such human−wildlife conflict needs further investigations, and continuous monitoring of the area is indispensable.

Despite the effort of conservation organizations on potential loses of biota by establishing legally protected areas, many species are continuing to decrease within most of the protected areas of African nature reserves, where local species extinctions are directly linked to human activities (Brashares *et al*., 2001; Ogutu *et al*., 2009). Survey and monitoring programs permit evaluation of the sources and impacts of population dynamics (Loibooki *et al*., 2002). A systematic analysis of population trends and habitats is needed to mitigate the decline of biodiversity (Newmark, 2008; Ogutu *et al*., 2009). Proper understanding of key drivers behind human−wildlife conflicts

is of paramount importance in helping key stakeholders; wildlife managers, livestock keepers, land-use planners and policy makers to formulate informed plans and policies for sustainable wildlife conservation.

6. Conclusion and recommendations

The Dhati ecosystem and the DhWNP area are under intense human influence due to habitat destruction, hunting and overgrazing by domestic cattle. Among these, habitat destruction and hunting are the two most series threats to the biodiversity of the Park. Despite the multi-faceted anthropogenic influence in the Park, high diversity of large mammals is recorded during the present investigation. This includes the globally threatened species such as Lion (*Panthera leo*), Leopard (*Panthera pardus*) and Giant forest hog (*Hylochoerus meinertzhageni*) and the rare species like Orbi (*Ourebia ourebi*), Reedbuck (*Redunca redunca*) and Spoted hyena (*Crocuta crocuta*). Significant anthropogenic impact in the area caused local extripation of high conservation value species such as red dwarf forest buffalo (*S. c. nanus*), Roan antelope (*H. equinus*) and Lelwel hartebeest (*A. b. lelwel*). Despite the high population estimate of the African buffaloes recorded in the study area, the age structure of the population was biased to adult age class, which might cause population decline. Adult males within the herd were significantly low indicating high trophy impact in the area. The foraging and ranging behavior of African buffaloes vary with season governed by flood levels during the rainy season and by grass species quality, phenology and greenness during the flood season and late dry season. However, the seasonal homerange of the species is fragmented by agricultural expansion and settlements. Therefore, on the bases of these, the following recommendations are proposed for immadiete consideration of the concerned organs for appropriate actions:

- Further detail faunal investigation in and around Dhati Wolel National Park should be done repeatedly at annual intervals to know the trend in population ecology with stress in large mammals.

- Long term monitoring of the African buffaloes with special emphasis on reproduction is necessary.
- Urgent rehabilitation of fragmented seasonal homerange of large mammals is to be made.
- Urgent rehabilitation of largely destroyed high elevation area savanna grassland habitat that support majority of the large mammals during the rainy season is recomended.
- The intensive irrigation activities in the upstream of Dhati ecosystem should be stoped.
- Training and awareness creation of local community and Park scouts is essential for conservation of the habitats with its flora and fauna.
- Emphasis should be given to aleviate hunting activities in the area.
- Park boundary should be established and strictly controlled by responsible Government agency.

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Annex 1. Analysis of population status of African buffaloes in Dhati Wolel National Park during the dry season in Distance 6.2, Release 1

Model s

Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Cosine adjustments of order(s) : 3, 4, 5

Parameters	Estimate	%CV	df	95% Confidence Interval	
DS	0.89784E-01	18.29	10	0.62823E-01	0.12831
D	6.7527	21.13	10	4.8250	8.1520
N	12092.41	21.13	10	10638.0	14206.04

Annex 2. Analysis of population status of African buffaloes in Dhati Wolel National Park during the wet season in Distance 6.2 Release 1

Models

Half-normal key, k(y) = Exp(-y**2/(2*A(1)**2))

Cosine adjustments of order(s): 2, 3, 4, 5

Parameter	Point Estimate	Standard Error	Percent C. Variation	df	95% Percent Confidence Interval	
DS	0.8637	0.1849	15.68	10	0.852	1.59
D	6.231	2.555	12.60	10	5.511	6.96
N	10798.0	27.50	22.60	10	9285.0	13829.0

Annex 3. Correlation analysis of relative abundance of preferred grass species with frequency of by *Syncerus caffer*

Correlations

		Frequency of acceptance of grass species	Relative availability of grass species
Pearson Correlation	Frequency of acceptance of grass species	1.000	.418
	Relative availability of grass species	0.418	1.000
Sig. (1-tailed)	Frequency of acceptance of grass species	.	.000
	Relative availability of grass species	.000	.
N	Frequency of acceptance of grass species	234	234
	Relative availability of grass species	234	234

Annex 4. Correlation analysis of percentage of green leaves effect on grass species frequency of acceptance by *Syncerus caffer*

Correlations[a]

		Grass species acceptance frequency	Percentage of green leaves
Std. Cross-product	Grass species acceptance frequency	1.000	.935
	Percentage of green leaves	.935	1.000
Sig. (1-tailed)	Grass species acceptance frequency	.	.000
	Percentage of green leaves	.000	.
N	Grass species acceptance frequency	123	123