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Table of Contents: Volume 9 Number 4, April 2017

ARTICLES

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Full Length Research Paper

"Diet analysis of the African clawless otter (*Aonyx capensis*) in and around Lake Tana"

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The diet composition of the *African clawless otter* (*Aonyx capensis*) was studied by analyzing of 440 spraint samples collected during January, 2014 and December, 2015 in both dry and wet seasons from eight sites in and around Lake Tana, North West Ethiopia. Percentage frequency of occurrence and relative percentage frequency of diet items in the spraint samples were calculated.The statistical analysis was conducted using chi-square and one-way ANOVA tests.The number of diet categories per spraint ranged from 1 to 4 with a mean of 1.42 ± 0.591. Fish was the dominant prey item in all sites with an overall frequency of occurrence of 84.77% and a relative percentage frequency of 59.68%. *Labeobarbus* spp. was the most frequent fish prey (35.45%). Crabs were the second most frequent prey items with percentage frequency of 33.41% and a relative percentage frequency of 23.52%, while small mammals and birds were the least frequent dietary items with percentage frequency of 0.45 and 0.23%, respectively. Other identified diet items and the respective percentage frequency were plant matter (6.17%), insects (5.68%), amphibians (5%), mollusks (2.5%) and unidentified items (3.86%). Variation on fish and crab prey items were observed between seasons and sites, while no variation was observed for other prey items. The results suggested a dietary flexibility and shift in the *African clawless otter* from crabs to fish that can be explained by availability and accessibility.

Key words: African clawless otter, *Aonyx capensis*, food items, Lake Tana.

INTRODUCTION

Otters belong to Order Carnivora,Family Mustelidae, Sub-family Lutrinae characterized by long streamlined bodies, fine dense hair and scent glands at the base of the tail (Kruuk, 2006). They are a unique group among carnivores due to their adaptation to semi-aquatic mode of life (Foster-Turley, 1990). Otters obtain most of their

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food from water, whereas reproduction and resting take place on land (Mason and Macdonald, 1986). They are one of the top predators of aquatic ecosystems and key-stone species of wetland environments (Mason and Macdonald, 1986; Ottino and Giller, 2004).

There are 13 extant species of otters of which three are limited to Sub-Saharan Africa (Nel and Somers, 2007). These are the Congo clawless otter (*Aonyx congicus*) limited to the Congo basin; the *African clawless otter* (*A. capensis*) occurring in most parts of western, eastern and southern Africa and the Spotted-necked otter (*Lutra maculicollis*) occurring in most parts of western, central and south-eastern Africa (Nel and Somers, 2007). The latter two species are found in Ethiopia (Yalden et al., 1996).

The *African clawless otter* is listed as 'Near Threatened' in the IUCN Red List for habitat loss (Jacques et al., 2015). It is the most widely distributed otter species in Sub-Saharan Africa ranging from Senegal in the west and Ethiopia in the east; also extending to southern Africa, but not in the central African rainforest region of the Congo Basin and arid areas (Rowe-Rowe and Somers, 1998; Kruuk, 2006; Nel and Somers, 2007; Jacques et al., 2015).

The African clawless otter is adapted to feed on crustaceans using its large molars and premolars for crushing the exoskeleton of its prey (Hussein et al., 2011). In freshwater habitats, the African clawless otter is generally regarded as crab eater, but it also consumes a variety of items including fish, amphibians, reptiles, aquatic insects, worms, crustaceans, birds and small mammals (Row-Rowe, 1977; Rowe-Rowe and Somers, 1998). According to Kingdon (1977), freshwater crab is an important prey of African clawless otters in most areas, but in some marshes, mussels and large aquatic snails may be more common prey item, while in swamps and rivers fish are also important prey items. Other food items, such as amphibians, water fowl and their eggs, monitor lizards, crocodile eggs, cane rats and other rodents are also consumed (Kingdon, 1977). Generally, African clawless otters are regarded as crab eaters, but in some areas, where crustaceans are absent or rare, fish was the dominant food item (Watson and Lang, 2003).

The diet of African clawless otter has been studied by Kruuk and Goundswaard (1990) in Lake Victoria, Butler and du Toit (1994) in Zimbabwe, Rowe-Rowe (1977), van der Zee (1981), Verwoerd (1987), Perrin and Carugati (2000), Somers (2000), Somers and Nel (2003), Watson and Lang (2003), Jordaan et al. (2015) in South Africa and Ogada (2006) in Kenya. However, scientific data on the ecology of the species in Lake Tana is not available and elsewhere in Ethiopia is not available. A recent study conducted by the authors in Lake Tana suggested the presence of fishermen-otter conflict.

According to this study, all 204 fishermen interviewed felt that otters cause conflict by depredating netted fish and damage of fish nets. As a result, the fishermen expressed negative attitude towards otters (Ergete et al., 2016, unpublished data). Due to the complete lack of research and conservation attention on these populations, the potential conflict with fishermen could go unnoticed and result in adverse effect. Thus, the objective of this study was first; to add on the available data on the feeding diet of *African clawless otter* in African. Our current knowledge is inconclusive and mainly based on research conducted on South Africa populations (van der Zee, 1981; Verwoerd, 1987; Perrin and Carugati, 2000; Somers, 2000; Somers and Nel, 2003; Watson and Lang, 2003; Jordaan et al., 2015). We attempted to test if crabs are the preferred prey as observed in previous studies (Rowe-Rowe, 1977; Nowak, 1991; Butler and du Toit, 1994; Lavriviere, 2001; Carugati and Perrin, 2003; Somers and Nel, 2003) or there is a potential to shift to other prey such as fish as reported in others (Verwoerd, 1987; Somers, 2000). Second, the otter is one of the neglected species research and conservation wise in Ethiopia. This study attempted to generate data on the diet of the *African clawless otter* and explored if fish are the dominant diet in Lake Tana. By highlighting the importance of fishermen-otter conflict, we attempted to attract research and conservation attention towards this population.

MATERIALS AND METHODS

The study area

Lake Tana is located in the North-western part of the Ethiopian Highlands about 565 km from the capital Addis Ababa, at coordinates 11°36'02.5'' and 12°14'25.5''N and 37°01'33.6" to 37°24'03"E (Figure 1) at an altitude of 1785 m asl (Poppe et al., 2013). It is Ethiopia's largest lake and a source of the Blue Nile, which contributes for around 85% of the river's water (Dejen et al., 2009; Getahun and Dejen, 2012). The total surface area of Lake Tana is around 3150 km^2 with a catchment area of 16,500 km^2 (Dejen et al., 2009) stretching approximately 84 km long and 66 km wide. It is a shallow non-rift valley lake with an average depth of 8 m and maximum of 14 m. Lake Tana is also a reservoir of half of the country's freshwater resources (Dejen et al., 2009). There are seven permanent rivers; Gilgel Abay (Little Abay), Megech, Gumara, Rib, Geleda, Arno-Garno and Dirma Rivers that feed the lake (Lamb et al., 2007; Heide, 2012). The Blue Nile (locally called '*Abbay*') River is the only outflow at the southern tip of Lake Tana. The climate around Lake Tana and its associated wetlands is of warm-temperate tropical highland monsoon with little mean annual temperature variation throughout the year (19°C in December to 23°C in May with an average of 21.7°C) (Heide, 2012). The rainfall pattern is unimodal and the mean annual precipitation ranges between 800 and 2000 mm with peaks between July and September (Dejen et al., 2004).

Methods

The universal method for obtaining information on the diet

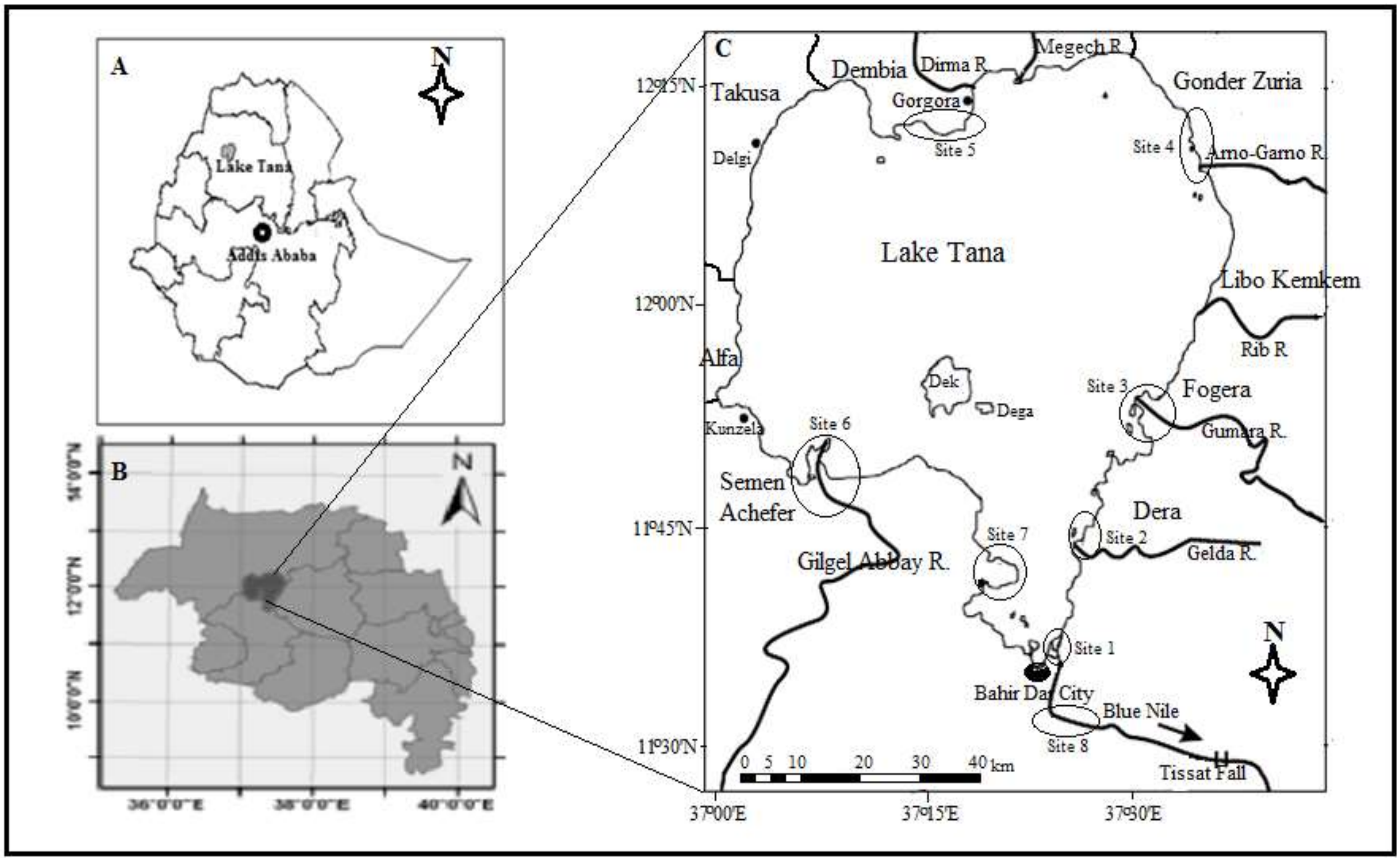

Figure 1. Map of (A) Ethiopia showing the location of Lake Tana, (B) Amhara Regional State and (C) Lake Tana showing the major tributaries and the out flowing river Blue Nile and the eight spraint sample collection sites.

composition of otters is based on the identification of prey remains in the spraints, because most parts of the skeleton of prey are left undigested (Kruuk, 2006).Aiso the *African* clawless otter is shy and nocturnal, thus spraint analysis is the most feasible option of studying its diet. A total of 440 spraints from eight sites were collected for two years between January, 2014 to December, 2015 for both wet (June - September) and dry (November - May) seasons. The sampling sites were described and distributed along the shore of Lake, on the Lake Islands and the main river systems of the Lake (Figure 1 and Table 1). Spraints of the *African clawless otter* were identified from related species in the area such as the spotted-necked otter (*Lutra maculicollis)* and the marsh mangoose (*Atilax paludinosus)* based on their large size, strong odor deposition shape and substrate (Rowe-Rowe, 1977). Spraints were collected from common latrines, den entrance and wallowing sites. Time and date, location, season, habitat feature and substrates were recorded for each spraint. Spraints were air dried and stored in polyethylene plastic bags until analysis.

Sprainats were analyzed at the Zoology Research Laboratory of the Department of Zoological Sciences, Addis Ababa University following Somers and Nel (2003). They were soaked in liquid detergent overnight in 250 ml of beaker to remove sand, debris and other binding mucilages. Then, the samples were washed under running water by using an iron sieve of mesh size 500 µm and carefully transferred to a sheet of paper and left for 24 h to dry at room temperature. Prey remains from the cleaned spraint were examined by using a hand lens and stereo microscope.

The prey items were categorized as fish, crab, amphibian, mollusc, bird, small mammal, insect, plant matter and unidentified item. Crabs, mollusks and insects were identified based on their characteristic exoskeletons. Fish remains were identified mainly by the shape of vertebrae, scales, otoliths, operculae, jawbones, teeth and pharyngeal bones. Amphibians were identified from sacral vertebra and ilium bones; birds by their feathers; and small mammals from fur, and heterodont dentition. Obliterated items which were difficult to put under any of the above prey groups were categorized as unidentified. A reference collection including photos was made of the bone of the fish items for further identification. Fish species were identified based on presence/absence of scale and dentition. Members of the Family Clariidae have no scales. Cichilidae have small scales. Cyprinidae lack teeth on their jaws but possess pharyngeal teeth. Also, they have large scales. The two genera in Cyprinidae were identified based on scale patterns. A Guide book on the fishes of Lake Tana (Getahun and Dejen, 2012) was used as a reference in the taxonomic identification of the fish items.

Data analysis

The diet composition was analyzed using frequency of occurrence which is the total number of occurrence of a food item, percentage

Table 1. Location and discription of sampling sites in and around Lake Tana.

Sampling site	Location	Lake shore and river bank habitat type description
Site 1	Debremariam island, Shum Abo and Cherechera	Dominated by forest vegetation, reed beds and rocky habitats densely covered by shrubs, trees and reed beds
Site 2	Bet-Menzo islets, Korata area and including Geleda River	Sites characterized by short grass, pasture as well as cultivated land and Rocky areas covered by vegetation
Site 3	Tana Kirkos peninsula, Wagetera and Gumara River	Site densely covered by vegetations, grass, farm lands, rocky areas, wetland and reed beds
Site 4	Mitreha Abaworka and Arno-Garno River	Farm land and wetlands are common and covered by grass and cultivated land
Site 5	Gorgora	Rocky shore with vegetation, farmland, wetlands as well as reed beds
Site 6	Gilgel Abbay and its Delta	River banks covered by farmland, pastureland, wetlands, and densely covered by shrubs, trees, reed beds and rocky areas
Site 7	Zegie Peninsula including Yeganda and Ambo Bahir wetlands	Sites covered by farm lands, forest vegetation with rocky as substrate, grasslands, wetlands, as well as reed beds
Site 8	Blue Nile River	Riverine forest vegetations, rocky, reed beds are common

frequency of occurrence and relative percentage frequency of occurrence of each food item. The percentage frequency of occurrence of the prey item was calculated as:

$PF = [(n_i/N)*100]$

Where: n_i = the number of spraints in which the i^{th} item occurred;

N = the total number of spraints.

The relative percentage of frequency, of occurrence was given as

: $RPF= [n_i/\sum (n_i+n_{ii}+...n_x)*100]$

Where: RPF = Relative percentage of frequency;

n_i = frequency of occurrence of the i^{th} item;

$\sum (n_1+n_2+...n_x)$ = the sum of the frequency of occurrence of all item.

The difference in the number of diet items per spraints were compared using the Chi-square nonparametric test. The seasonal variation in occurrence of diet categories and the spatial variation of occurrence of the two dominant diet items, fish and crab, between the eight sampling sites, were compared using one way ANOVA. Post hoc Tukey test was used to deternmine the level of significance in seasonal and spatial variation. For all tests, the significance level was determined at the 95% confidence interval.Data were analyzed on SPSS statistical software ver. 20.

RESULTS

Diet composition

A total of 440 spraints of the *African clawless otter* were collected from the eight sampling sites. More samples were collected during the dry season (242) than the wet season (198) and the difference was significant (χ^2 = 4.40, df = 1, P < 0.05) (Table 2). Nine prey categories (fish, crab, amphibian, mollusk, bird, small mammal, insect, plant matter, and unidentified) were identified from the spraints with a mean number of 1.42 ± 0.591 prey types per spraint. Most of the spraint samples (>63%) contained a single prey item while less than 1% of the samples contained four items and none of the spraints contained more than four items. The difference in number of diet items per spraint was significantly different in both seasons (χ^2 = 444.49, df = 3, P < 0.05) (Figure 2). Fish was the dominant diet with overall percentage frequency of 84.77%. Cyprinidae was the most frequent fish family (46.36%) *Labeobarbus* spp. was the most common fish species in the diet (35.45%). Other fish species in the diet were *Clarias gariepinus* (Family Clarridae, 17.04%) and *Oreochromis niloticus* (Family Cichlidae, 21.36%) (Table 3). Crabs were the second important prey items with percentage frequency of 33.41%. The remaining prey groups had an overall contribution of less 10% with small mammals and birds being the least frequent dietary items (0.45 and 0.23% respectively) (Table 3).

Seasonal variation

The percentage frequency of fish was significantly higher during the wet season (96.97%) than the dry season (74.80%) ($F_{1\ 438}$ = 45.600, P < 0.05), while crabs showed

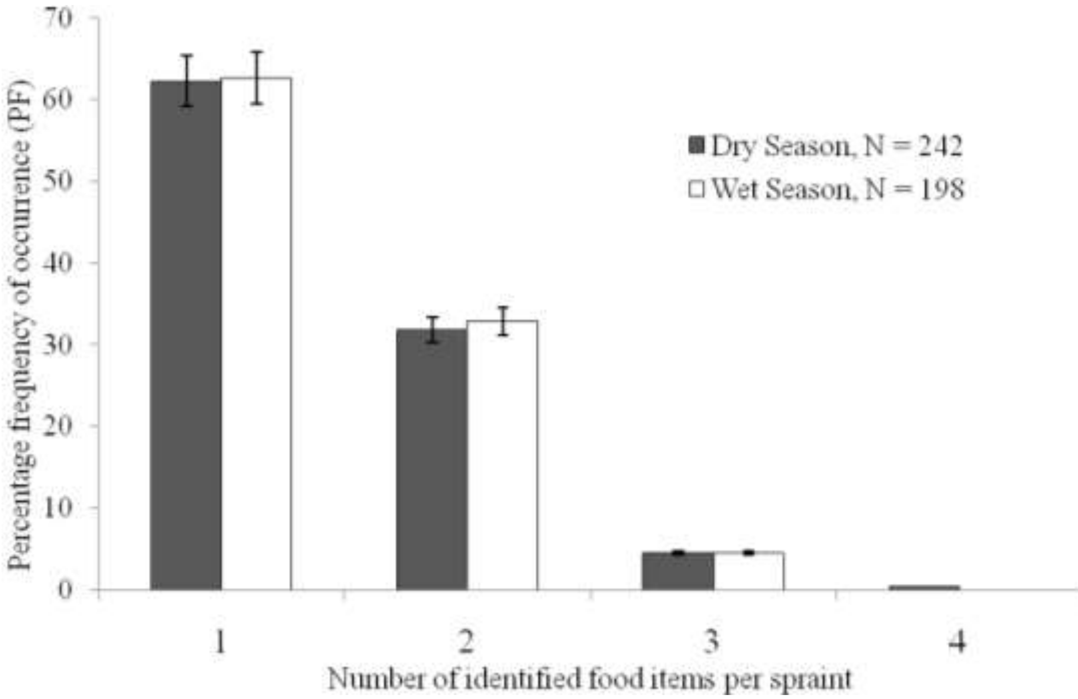

Figure 2. Number of diet items per spraint during dry and wet season.

Table 2. The number of spraints of *Aonyx capensis* collected from eight sampling sites during the wet and dry seasons.

Seasons	Sampling sites								Total
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	
Wet	21	15	22	20	17	57	23	23	198
Dry	46	31	18	23	19	51	27	29	242
Total	67	44	40	43	36	108	50	52	440

significantly higher percentage occurrence during the dry season (40.50%) than the wet season (24.75%) ($F_{1\ 438}$ = 12.428, P < 0.05). Amphibians showed the reverse trend decreasing from 8.08% in the wet season to 2.48% in the dry season ($F_{1\ 438}$ = 7.280, P < 0.05), (Table 3). Birds and mammals were missing from the dry season samples while the remaining (mollusks, insects, plant matters and unidentified) items occurred in both seasons with no significant seasonal variation (P > 0.05) (Table 3).

Spatial variation in diet composition

Birds and small mammals diets were restricted to one and two sampling sites respectively while the remaining items were common for all the sampling sites (except molluscs which were not recorded from three sites) (Figure 3). Fish showed a significantly highest frequency of occurrence in site 6 (93.52%) and lowest in site 1 (73.13%) ($F_{7\ 432}$ = 2.765, P < 0.05). Tukey test showed significance difference between Site 6 and 1 while there was no difference with the rest. The difference in percentage frequency of occurrence of crabs was also showed significantly spatial variation with highest value from site 1 (52.24%) and lowest from site 6 (14.81%) ($F_{7\ 432}$ = 5.777, P < 0.05). Tukey test showed significant difference between site 1, 4 and 6 (Figure 3). The other diet items did not show significant variation in their percentage frequency of occurrence among the sampling sites (P > 0.05) (Figure 3).

DISCUSSION

The results showed that the diet of the *African clawless otter* is composed of a broad trophic niche. Similar

Table 3. Occurrence (O), percentage frequency of occurrence (FO) and relative frequency of occurrence (RFO) of food items in the spraints of the African clawless otter during dry and wet seasons in and around Lake Tana.

Prey type	Wet (N = 198) O (PF)	Dry (N = 242) O (PF)	Overall O (PF)	RFO
Fish	192 (96.97)	181 (74.80)	373 (84.77)	59.68
Clarridae (*Clarias gariepinus*)	40 (20.20)	35 (14.46)	75 (17.04)	(12.00)
Cichilidae (*Oreochromis niloticus*)	52 (26.26)	42 (17.36)	94 (21.36)	(15.04)
Cyprinidae	100 (50.51)	104 (42.96)	204 (46.36)	(32.64)
Barbus spp.	25 (12.63)	23 (9.50)	48 (10.91)	(7.68)
Labeobarbus spp.	75 (37.88)	81 (33.47)	156 (35.45)	(24.96)
Crabs	49 (24.75)	98 (40.50)	147 (33.41)	23.52
Amphibians	16 (8.08)	6 (2.48)	22 (5.00)	3.52
Mollusks	3 (1.52)	8 (3.31)	11 (2.50)	1.76
Birds	1 (0.50)	0	1 (0.23)	0.16
Small mammals	2 (1.01)	0	2 (0.45)	0.32
Insects	16 (8.08)	9 (3.72)	25 (5.68)	4.00
Plant matters	16 (8.08)	11 (5.55)	27 (6.17)	4.32
Unidentified	6 (3.03)	11 (5.55)	17 (3.86)	2.72

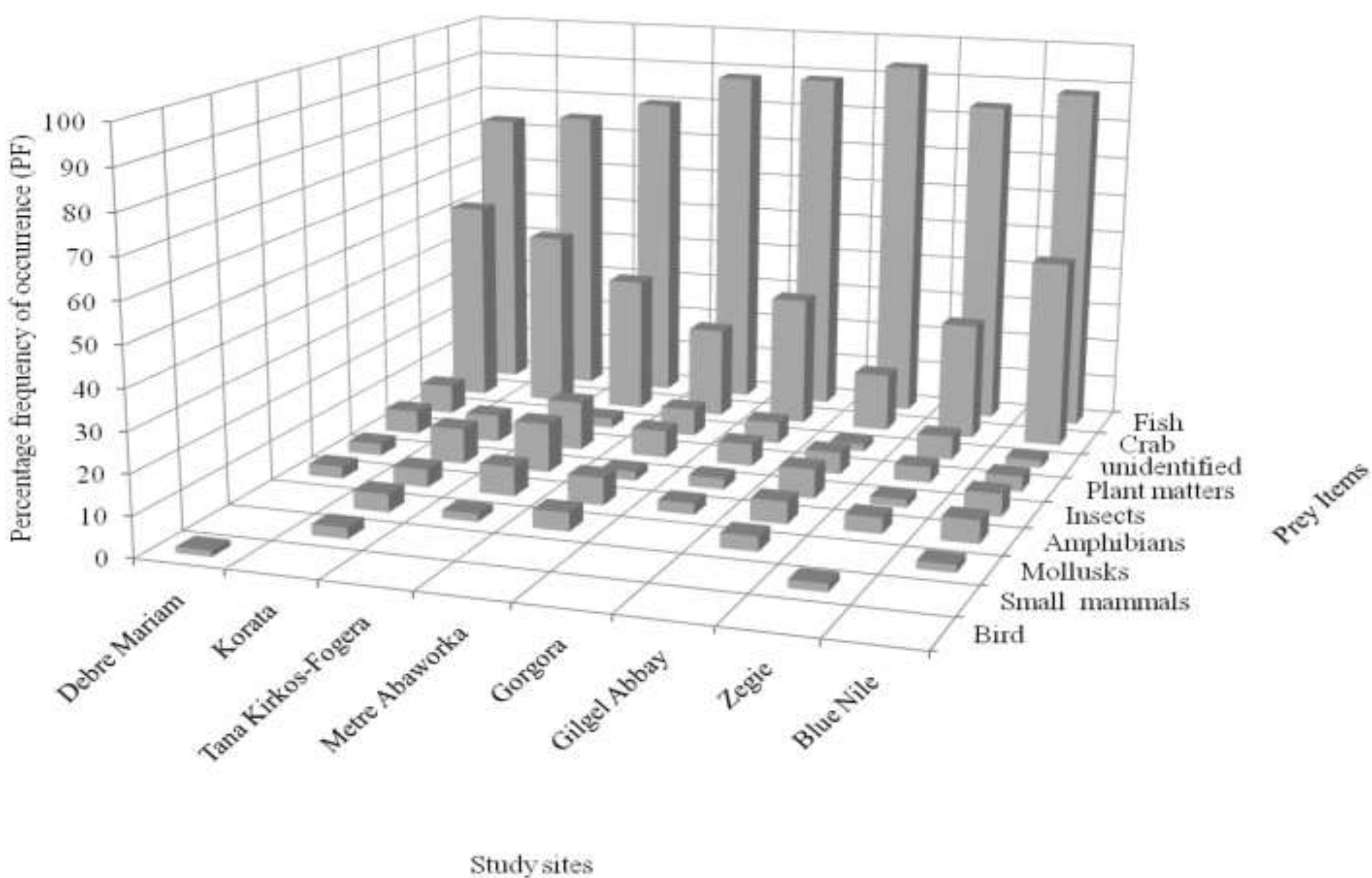

Figure 3. Study site variation in prey composition (Percentage of occurrence) of African clawless otter in the study area.

observations were reported previously where the diet included fish, crabs, birds, dragonfly larva, insects, mollusks, reptiles, rodents, shrews, and seaweeds (Nowak, 1991; Rowe-Rowe and Somers, 1998; Lariviere, 2001;Watson and Lang, 2003).This was in contrast with that of the Eurasian otter (*Lutra lutra*) which had only five diet items; fish, amphibians, birds, mammals and insects in different freshwater habitats (Krawcrzyk et al., 2016). Although mollusks, insects, amphibians and other items were abundant in and around Lake Tana (Pers. Obs.), they were not largely taken by *African clawless otter* and also predation on bird and small mammals was very rare. The same result was reported by Rowe-Rowe (1977, 1978) and Butler and du Toit (1994) indicating that mammals and birds formed a very small amount of the diet of otters in South Africa and Zimbabwe, respectively. Insects had a very low percentage frequency of occurrence (5.68%) in the present study which contrasts the 19% occurrence reported from the Eastern Cape Province, South Africa (Somers and Purves, 1996).

The present study sheds new insight on our knowledge of the diet composition of the African clawless otters. Previously, crabs and other crustaceans were regarded as the preferred and primary prey while fish, mollusks, and frogs were secondarily important (Rowe-Rowe, 1977; van der Zee, 1981; Arden-Clarke, 1986; Kruuk and Goudswaard, 1990; Nowak, 1991; Butler and du Toit, 1994; Ligthart et al., 1994; Kingdon, 1997; Somers, 2000; Lariviere, 2001; Somers and Nel, 2003; Emmerson and Philip, 2004; Ogada, 2006; Jordaan et al., 2015). Our study showed that fish was the dominant prey item in and around Lake Tana during both wet and dry seasons. A study conducted on fishermen attitude and conflict with otters in and around Lake Tana also suggested that fish was the dominant diet item (Ergete et al., 2016, unpublished data). In light of these results, the diet selection and foraging behavior of the *African clawless otter* showed flexibility. Local flexibility and variation of the diet was also reported in the following previous studies. In Batty's Bay area of the Western Cape Province of South Africa, fish was the most important prey category (59% of biomass) followed by octopus (15%), crab (13%) and lobster (10%) (Verwoerd, 1987). Watson and Lang (2003) reported 69% relative frequency of fish in the diet of *African clawless otter* in Groenvlei Lake, South Africa. In coastal waters of the Cape Province of South Africa, the most important prey categories of African clawless otter were 50% fish, 28% crabs, 11% lobster and 6% abalone (Somers, 2000). Dietary shift was also recorded in the Eurasian otter. A diet analysis study conducted in Shapwick Heath, UK, showed that the proportion of birds (41%) showed a significant increase compared to previous studies in Slapton Ley in 1981 (4.6%) and Somerset Levels in 1975 (4.71%) (de la Hey, 2008).

We suggest that the dietary flexibility of the African clawless otter might be governed by opportunism. Currently, there are commercial fishing practices in all of the eight sampling sites of the present study area *The African clawless otter* might adapt to foraging on netted fish which is more profitable than actively searching and capturing crabs or other prey. This will apparently incur energetic costs with uncertain probability of success compared to depredation of netted fish.This was also supported by the presence of fishnet remains which were observed in some of the spraints of *African clawless otter* in the present study. In addition the study on fishermen attitude and conflict with otters (Ergete et al*.,* 2016, unpubl. data) indicated that *African clawless otter* caused loss of captured fish and damage of fishing equipment in the present study area. Similarly, the *African clawless otter* is reported to shift its diet from crabs to fish in areas where crustaceans are rare (Watson and Lang, 2003).

The dietary contribution of the different fish species may show correlation with their abundance. There are 17 species that belong to the genus *Labeobarbus* in Lake Tana compared to only three species of *Barbus* (Getahun and Degen, 2012). The former is apparently a more diverse group and contributed the highest proportion of the diet. Two other genera (*Gara* and *Varicorhinus)* within Family Cyprinidae were not represented in the spraints. This might be due to their small population size in the study area (Getahun, Pers. Com.). In the Eurasian otter, the dietary contribution of fish was influenced by seasonal changes and preference while there was no correlation with population size. In this species, *Leuciscus cephalus* was the preferred fish diet which was also most commonly consumed in the cold season while *Capoeta* spp. was dominant during the warm season (Mirzaei et al., 2014).

The diet of the *African clawless otter* like other species of small-clawed otters (Kanchanasaka and Duplaix, 2011), spotted-necked otter (Perrin and Carugati, 2000), European otter (Sales-Luis et al., 2007) and the American river otter (Melissa, 2006) showed a seasonal variation in its diet. The high percentage occurrence of fish in the wet season diet of the *African clawless otter* may be explained by the spawning migration behaviour for reproduction in their breeding sites to the rivers and shores. Anteneh et al. (2012) reported that the spawning migration of fish from Lake Tana through rivers and wetlands has a wet season peak (July to October) while their spawning was also slowed by low water temperatures. This behavior might rendered the fish more vulnerable to predation in the wet season. Additionally, some species such as *Oreochromis niloticus* breads, grow and feed among the macrophytes at shallow areas of the shore and associated wetlands (Getahun and Dejen, 2012). Rowe-Rowe (1977) reported that the seasonal patterns of prey in the diet might be related to ease of capture of the prey which was affected by water temperature and level.In contrast to fish,more crabs were

consumed by *African clawless otter* during the dry season. This might be due to the decrease in the water level during the dry season that allowed the *African clawless otter* to find and capture crabs easily to locate and capture under and/or between the rocks near shore.
Similar results were reported by Somers and Nel (2003) in the Olifants and Eerste Rivers in the Western Cape Province. Plant matters in the diet were higher in the wet and lower in the dry. In the dry season plant matters was rare on the river banks and on most parts of the shore of the Lake (Pers.Observ.). Most probably, the plant matter observed in the diet was ingested accidentally. Lariviere (2001) indicated that seaweeds are among the food items taken occasionally by African clawless otter. The consumption of vegetation may depend on the species and the season (Reyes, 2007). The difference in the diet of prey items between seasons in the study area may be affected by factors such as climate, human disturbance, water temperature, presence and absence of reed beds, prey availability and abundance (Verwoerd, 1987; Somers, 2000).

The spatial differences in diet composition in the study area may be due to the occurrence of prey, behavioral adaptation of the African *clawless* otter and preference of Rivers than Lakes. Studies by Rowe-Rowe (1977) in Natal the African clawless otters spent more time hunting in the tributaries and the distribution of scats indicated a similar pattern. The *African clawless otter* showed different diet profile in different areas (Kruuk, 2006) Across most of its ranges,crustaceans were the main prey, while in this study fish was the most preferable prey item. This variation in the diet of *African clawless otter* in different sites may be due to different topographic features and prey availability rather than a result of prey selection. Emmerson and Philip (2004) reported that the diet of *African clawless otter* varies with site due to the wide distribution throughout Sub-Saharan Africa. Studies by Baltrunaite (2009) in Lithuania also noted that changes in the diet of otters are related to different habitat. Rowe-Rowe (1977) and Rowe-Rowe and Somers (1998) also reported that diet of the African clawless otter varies depending on locality, season and prey availability.

In conclusion, the present study suggested that the *African clawless otter* can adapt to a fish dominated diet based on availability and ease of access as opposed to the previous knowledge that crabs are universally dominant. The study also strengthens previous knowledge that crabs and fish constitute the core diet of *African clawless otter* which is supplemented by amphibians, insects, mollusks, plant matter and occasionally birds and mammals.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

A survey on species diversity, abundance and community structure of woody plants in burial sites in Gobeya Rural Administrative of Tehuledere District, South Wollo, Ethiopia

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Tropical forests generally host high biodiversity and are important sources of ecological, socio-cultural and economic services. There are also many sacred forests in many parts of the world, including burial sites in Gobeya rural administrative, having a significant ecological and socio-economic value. This study aims to quantify species diversity, abundance and vegetation structure, and also to determine the ecological importance of woody plant species in burial forest sites. The study was carried out between February and April, 2015 in Gobeya rural administrative which is located approximately at 430 km North of Addis Ababa, Ethiopia. Three largest burial sites (Sideni, Merma and Gubahil) were inventoried where three quadrats of 20 × 20 m at 100 m interval around the edge, and other three quadrats of 20 × 20 m at 50 m interval around the interior were randomly laid. A total of 28 woody plant species belonging to 19 families and 26 genera were identified. Analysis of species rarefaction curve at 95% confidence level reveals that Sideni cemetery site tends to have the highest species richness (α-diversity, n=22) with a possibility of finding new species. Estimation of total species richness using Chao-1 also shows that Sideni site to have the highest richness (n=25). Similarly, non-metric multi-dimensional scaling (MDS) ordination shows that Sideni burial site appears to have the highest species turnover (β-diversity). This is probably due to the presence of an intermediate disturbance in Sideni burial forest site. On the other hand, *Acokanthera schimperi* (A. DC.) Benth. & Hook. f. (Apocynaceae) is the most abundant tree (56.32%) in Sideni site while *Carissa edulis* (Forssk.) Vahl (Apocynaceae) is the most abundant shrub in Merma site (29.34%) and Gubahil site (38.13%). In this regard, religious teaching takes the highest social motive behind the tradition of protecting burial sites in the study area. Burial sites provide many socio-economic services including firewood, construction products, livestock forage, medicinal plants and other household products. They also play as important refugia for wild animals such as hyena, fox, porcupine, monkey and many other bird species. So, protection of burial sites should be ensured over long terms, and the indigenous practices of protecting burial forest sites should be preserved. Therefore, burial sites can be delineated as an important landscape to protect and preserve these socio-economically important plant species.

Key words: Burial forest, diversity, abundance, species richness, species composition, multi-dimensional scaling (MDS).

INTRODUCTION

Tropical forests generally are the centers of biodiversity and high endemism, and are the greatest carbon sink and so regulating global warming. Like many tropical countries, Ethiopia is rich in biodiversity emanated from variation in agro-climatic conditions and altitudinal variability (Erenso et al., 2014). However, the country's forest resource has been degraded over several decades due to habitats change, deforestation and climate change (Aynekulu et al., 2011; Kacholi, 2014). Up to the end of 1992, studies revealed that Ethiopian forest coverage has declined from the original 35% to an estimated 3 to 4% (Hundera, 2007). Such prolonged habitat reduction has remarkably changed the structure and species composition of forest landscapes (Echeverria et al., 2006).

In Ethiopia, there are several forms of forest conservation practices by local and religious communities (Mulat, 2013). These are traditionally managed small patches of remnant forest yet having a great potential for conservation of many species (Bhagwat and Rutte, 2006; Wassie et al., 2010). Similarly, the local peoples in Gobeya rural administrative of Tehuledere district have a long tradition of planting trees and conserving forests in burial sites. However, appropriate recognition of this management practice is not put in place so far by the government and other stakeholders. Management of such forest ecosystems at the local community level has numerous economic, social and cultural benefits as well as ecological services (Feyissa, 2001). Hence, species diversity should be inventoried to determine the importance of a particular landscape for conservation purposes. Alpha diversity is a measure of the number of species counted in a sample; Beta diversity is the rate of change in species composition along gradients, while Gamma diversity is the diversity of a region or a landscape (Whittaker, 1969; Colwell, 2009; Gotelli and Colwell, 2011).

To the knowledge of the researcher, there have not been any formal researches conducted on these sacred forest sites in the area, though the sites are important habitats for native and endemic plant species. In this regard, most burial sites in Gobeya rural administrative are covered with remnant of potentially native and socio-economically important plant species. So, this particular study is designed to quantify the species diversity, abundance and vegetation structure, and to document the ecological importance of woody plant in burial forest sites in Gobeya rural administrative of Tehuledere district, South-Wollo, Ethiopia. The study is expected to fill the gap of limited researches in the subject area. The survey also aims to promote conservation of burial forest sites across the region. The outputs of this study are expected to have a contribution for policy legislation and management of sacred forest resources in the district.

MATERIALS AND METHODS

Description of the study area

Gobeya rural administrative is one of the 19th rural administration units in Tehuledere district. According to 'Tehuledere Woreda Agriculture and Development Office (TWADO)', the study area is reported to cover a total area of 1293.75 ha. Information from TWADO shows that the area is divided into five land-use land-cover types (Figure 1). These include built-up area (86.85 ha), cultivated land (1070.6 ha), grassland (16.9 ha), shrub and bushland (118.8 ha) and water body (0.6 ha). This survey was conducted in three larger burial forest sites that have more than 1.5 ha each. The livelihood of the surrounding community is mainly agriculture. Most important crops harvested in the area include teff (*Eragrostis tef*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), wheat (*Triticum aestivum*), barely (*Hordeum vulgare*), common oat (*Triticum dicoccon*), chickpea (*Cicer arietinum*), field pea (*Pisum sativum*) and many other horticultural crop species.

Measuring species richness, diversity and abundance of woody plants

The study area has about seven burial forest sites with variable sizes. For this study, however, only three larger burial forest sites (Sideni, Merma and Gubahil), having a size of more than 1.5 ha, were selected as representatives to carry out the survey. Generally, 20 × 20 m quadrats were randomly laid across the edge and the interior-habitat. In particular, 3 quadrats of 20 × 20 m at each 100 footsteps interval around the edge-habitat and 3 more quadrats of 20 × 20 m at each 50 footsteps interval around the interior-habitat of each forest site. Areas within 30 m range from the edge line were considered as edge-habitats, and areas beyond 30 m from the edge line were regarded as the interior-habitats. Then, species richness, diversity and vegetation structure of woody plants in each site were surveyed according to methods adapted from Bonham (2013) and Smith and Smith (2001). The total numbers of individual shrubs/trees counted in each quadrat were regarded as abundance while the number individual trees and shrubs of each species in a hectare represented a density.

Identification of woody plant species

Locally recognizable or native plants were identified while in the field and their names were verified using Flora Books of Ethiopia and Eritrea (Hedberg and Edwards, 1989; Edwards et al., 1995; Hedberg et al., 2003). On the other hand, nearly eight unidentified plant specimens were transported to Addis Ababa University National Herbarium for processing and identification. Categorizing woody plant species into threatened and unthreatened was made based on personal observation on their local/regional abundance in the surrounding ecosystems to the burial forest sites.

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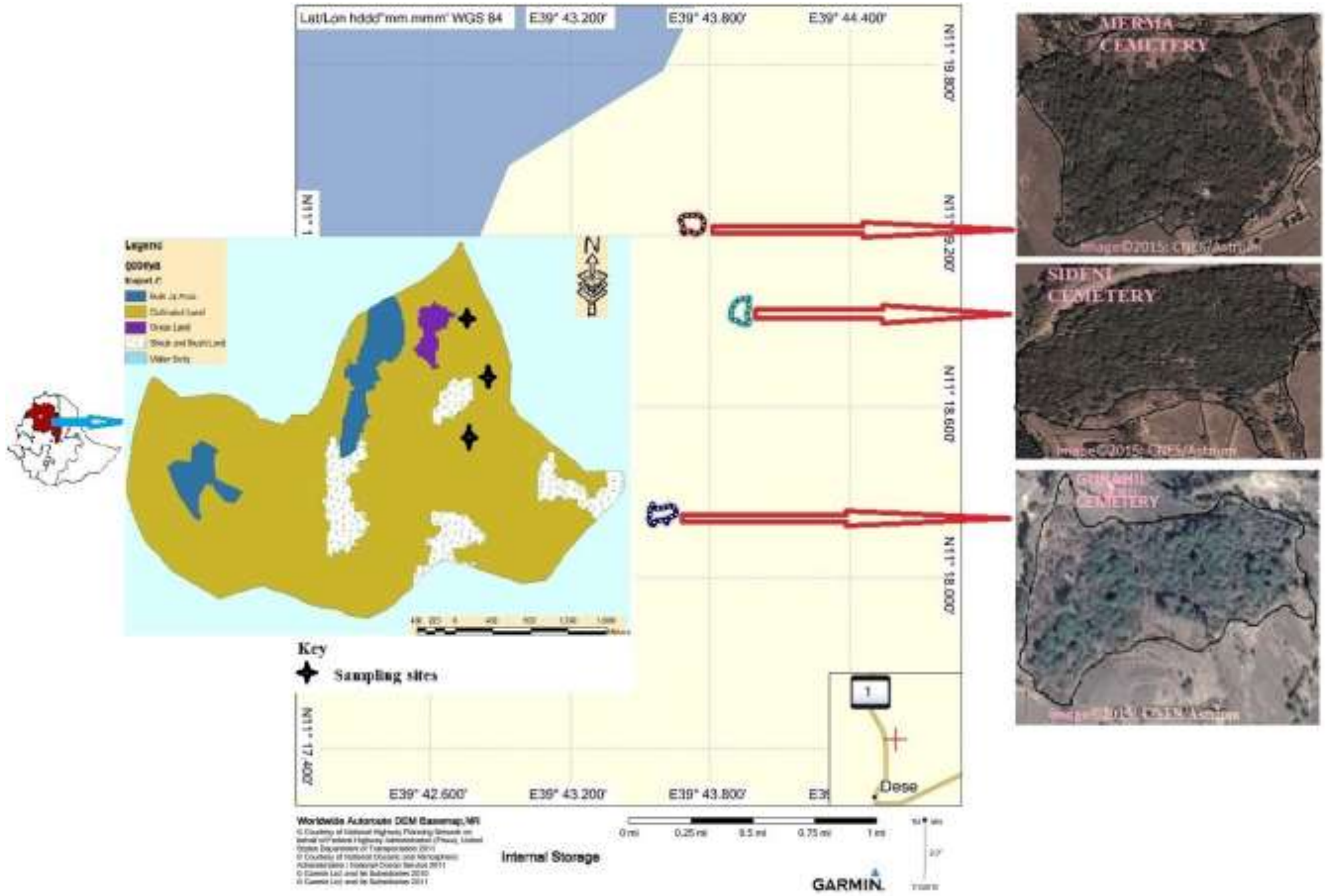

Figure 1. Map of the study area and sampling sites (GARMIN Ltd, TWADO and CNES/Astrium, 2015). Imagery spots on the right margin are the three sampling burial forest sites: Merma (on the top), Sideni (on the center) and Gubahil (on the bottom).

Data analysis

Multivariate data analyses including species rarefaction curve (to see the trend of species richness with sample size) and Chao-1 estimator (to extrapolate missing woody plant species in each sampling sites), and hierarchical clustering (to compare the level of species turnover and similarity in species composition between and within sampling sites) and non-metric multi-dimensional scaling (to clearly identify changes in species composition along the habitat gradients) were computed using 'PAST' version 3.06 (Hammer et al., 2001).

RESULTS AND DISCUSSION

Diversity and abundance of woody plants

A total of twenty eight (N=28) woody plant species were recorded from all sampling sites combined. Of these, twenty seven species are found to be angiosperms (flowering plants) while only one species (*Juniperus procera* Hochst. ex Endl.) is a gymnosperm (non-flowering plant). Similarly, almost all species (n=27) are proven to be native to Ethiopia while only one species (*Eucalyptus camaldulensis* Dehnh.) is found to be an exotic one (Table 1). The species are belonging to 19 families and 26 genera. Family Fabaceae is found to have 4 species, and Apocynaceae, Boraginaceae, Euphorbiaceae, Oleaceae, Santalaceae and Verbenaceae are represented by 2 species each, and the remaining families have only one species each.

The study sites are located somewhat in the same ecological zones that it was expected to come across with similar species compositions in the study sites. Apparently, some shared woody plant species were discovered among the sampling sites. So, only nine woody plant species including *Carissa edulis*, *Acacia abyssinica*, *Ocimum sauve*, *Olea europaea*, *Acacia negrii*, *Pterolobium stellatum*, *Jasminum abyssinicum*, *Grewia mollis* and *Calpurnia aurea* are found in all the three sites. Similarly, each forest site is found to support different number of woody plant species where a total of twenty two, seventeen and fifteen woody plant species are recorded in Sideni, Merma and Gubahil sites, respectively. A study by Denu and Belude (2012) reported an equivalent number of species in average in their study

Table 1. List and description of woody plant species documented in the study area.

Species (Botanical) name	Family	Species (Botanical) name	Family
Carissa edulis (Forssk.) Vahl.	Apocynaceae	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae
Acacia abyssinica Hochst. ex Benth.	Fabaceae	*Grewia mollis* Juss.	Tiliaceae
Croton macrostachyus Hochst.	Euphorbiaceae	*Cordia africana* Lam.	Boraginaceae
Ocimum sauve Willd.	Lamiaceae	*Celtis africana* Burm.f.	Ulmaceae
Rhus natalensis Bernh.	Anacardiaceae	*Clerodendrum myricoides* (Hochst.) R.Br. ex. Vatke	Verbenaceae
Premna schimperi Engl.	Verbenaceae	*Calpurnia aurea* (Ait.) Benth	Fabaceae
Olea europaea L. var. cuspidata (Wall. ex G.Don) Cif.	Oleaceae	*Maytenus obscura* (A.Rich.) Cufod.	Celasteraceae
Acacia negrii Pic.-Serm.	Fabaceae	*Myrsine africana* L.	Myrsinaceae
Acokanthera schimperi (A. DC.) Benth. & Hook. f.	Apocynaceae	*Ziziphus spina-christi* (L.) Desf.	Rhamnaceae
Pterolobium stellatum Forssk.	Fabaceae	*Eucalyptus camaldulensis* Dehnh.	Myrtaceae
Croton sp.	Euphorbiaceae	*Dodonaea angustifolia* L.f.	Sapindaceae
Juniperus procera Hochst. ex Endl.	Cupressaceae	*Bersama abyssinica* Fresen.	Melianthaceae
Pittosporum viridiflorum Sims.	Pittosporaceae	*Ehretia cymosa* Thonn.	Boraginaceae
Adhatoda schimperiana Hochst.	Acanthaceae	*Osyris quadripartita* Salzm. ex Decne.	Santalaceae

on ‘Floristic Composition of Traditional Sacred Landscapes in Bedelle Woreda, Illubabor Zone, Oromia Regional State, Ethiopia’.

Species rarefaction curves at 95% confidence level also shows that Sideni burial site is characterized by the highest species richness (α-diversity) where even new species are expected to be found if more sampling plots were included (Figure 2). The increasing trend of rarefaction curve indicates the possibility of discovering more plant species than what is actually found if more plots were included. This implies that Sideni cemetery could have more than 22 woody plant species if the whole population was surveyed. On the contrary, the rarefaction curves for Merma and Gubahil sites become flat as the number of individual counts (and so sampling sites) increase. An estimate of species richness using Chao-1 estimator (Figure 3) based on abundance of individual species also suggests that Sideni site could have three more missed species undocumented. This makes the site to possibly have 25 woody plant species. On the other hand, the other two sites (Merma and Gubahil) would only have 17 and 15 woody plant species, respectively. This suggests that the probability of finding new (rare) woody plant species is unlikely even more sampling site were incorporated during the survey. The lower plant species records in Merma and Gubahil burial forest might be related to the presence of very low disturbance regime. In both sites, it was observed that grazing and product extraction are very limited. In this regard, Graham and Duda (2011) reported as a low and high disturbance could reduce species spatial diversity in a given area.

The hierarchical clustering (Figure 4) shows that for each site, 5 out of 6 quadrats cluster together indicating that burial sites tend to have different species composition. With few exceptions, however, there seems to be limited variation of species compositions between quadrats of the same site. The hierarchical clustering also generally indicates the average percentage of species similarity between quadrats in each sampling site. Overall, Sideni site is characterized by high species turnover and species richness. As it was stated earlier, this might be due to the fact that the degree of disturbance is observed to be intermediate (and controlled) in the site so that it might have promoted species richness and diversity in the site.

The apparent changes in species composition were clearly observed on a non-metric MDS ordination (Figure 5), which clearly shows that species composition actually changes while moving along sampling sites, but not while moving along edge and interior-habitats. This indirectly implies that the edge-effect has no systematic effect everywhere for the changing species composition across the sampling sites. It is, however, worth to note that important changes in species composition of a quadrats compared to the other quadrats of the same site were observed only from edge-quadrats, that is, in the 1st quadrat of Sideni site and in the 3rd quadrat of Merma site.

Therefore, it can be suggested that the edge and interior-habitats appeared to have almost the same species richness and species turnover in all sampling sites. As it was observed that the edge-habitats always have no lower (or higher) species richness, it also become clear that edge-habitats showed no significant differences in species spatial assemblage as compared to the interior-habitats in each sites. However, Kacholi (2014) has reported as the edge-habitats showed lower

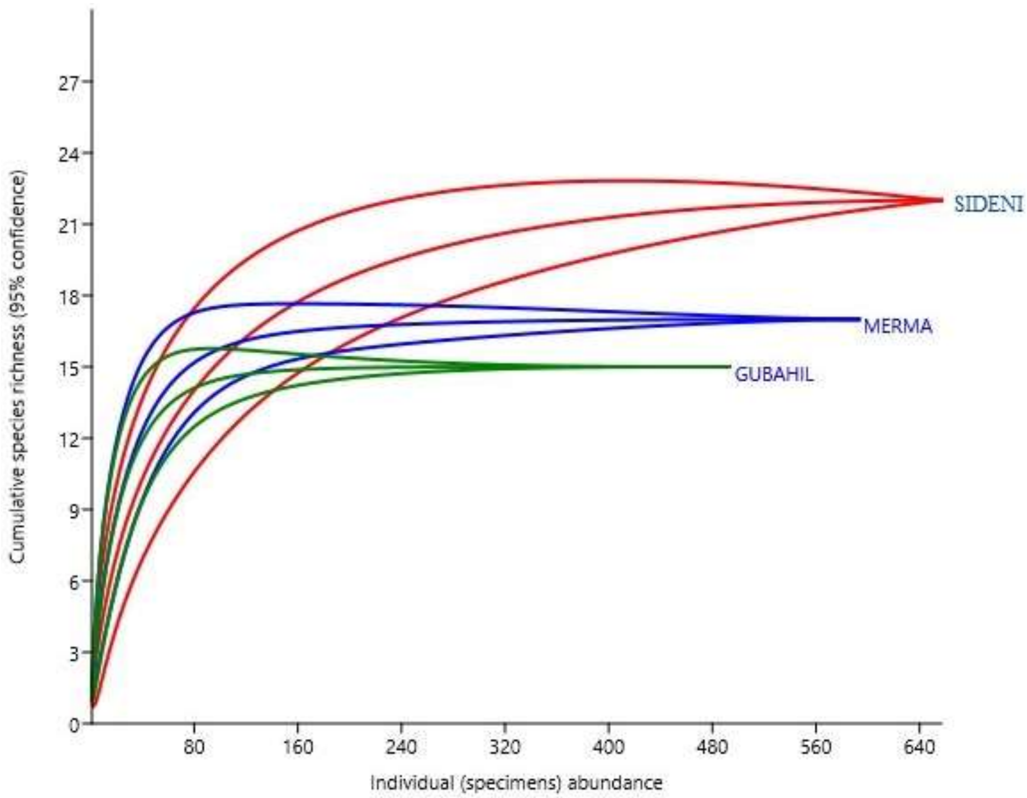

Figure 2. Rarefaction curves of cumulative increase of species richness (Mean ±SD) at 95% confidence for each sampling site: The curve is plotted for cumulative species richness as the function of individual woody plant species counts across the sampling sites.

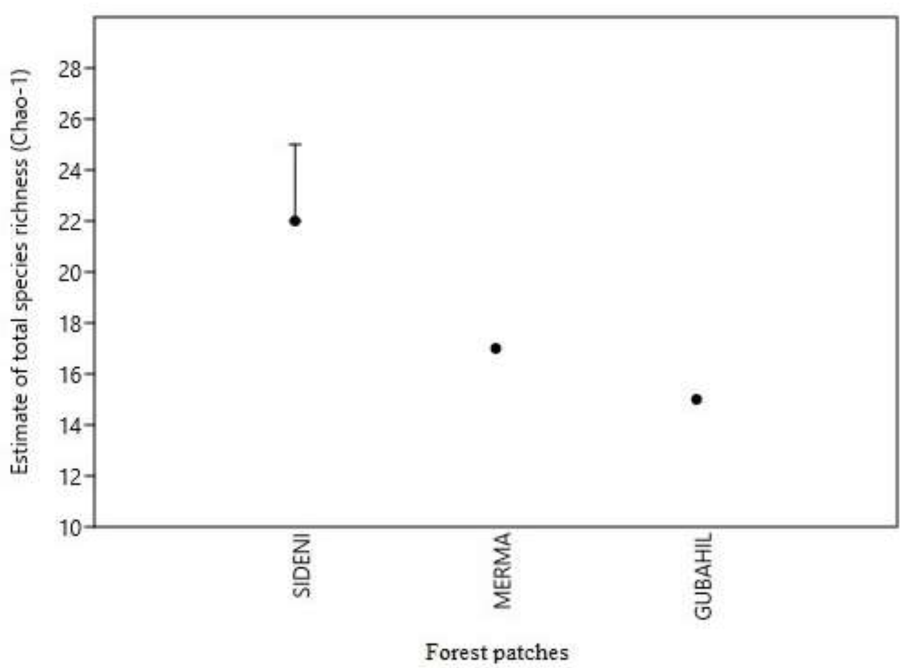

Figure 3. Total estimate of woody plant species richness (*Chao-1*) per forest sites. *Chao-1* estimator is extrapolated based on the number (and abundance) of individual species recorded in each site. Sideni site is estimated to have a maximum of 25 woody plant species.

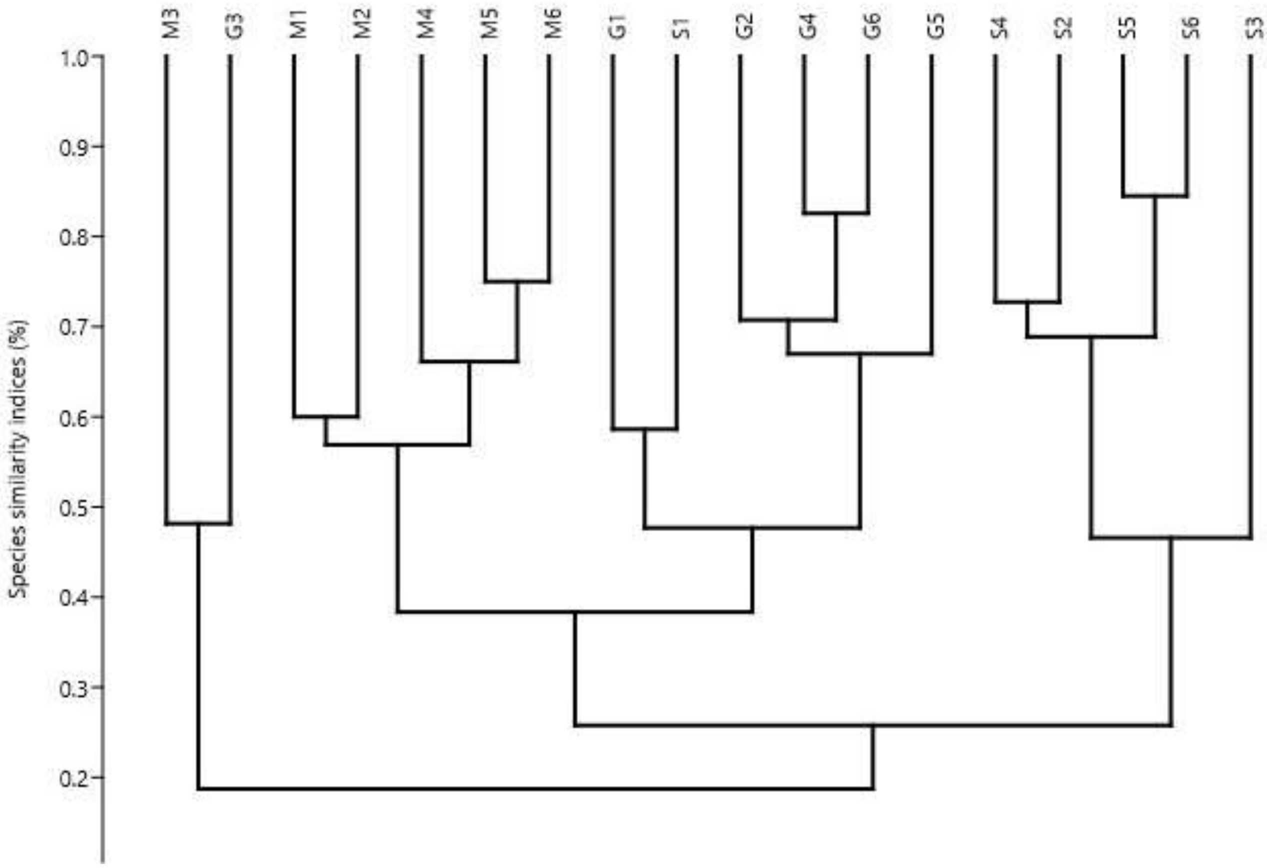

Figure 4. Hierarchical clustering (dendrogram) of sampling sites and quadrats based on Bray-Curtis similarity index showing the percentage of shared species within and between sampling sites. Note that S= Sideni, M=Merma and G=Gubahil and digits from 1 up to 6 stands for quadrats in each site; and quadrat 1-3 are edge-quadrats and 4-6 are interior ones.

species heterogeneity in his study at Kilengwe Forest in Morogoro Region, Tanzania. The higher species richness and species turnover (Figures 4 and 5) observed at Sideni site could be related to the presence of controlled and intermediate disturbance regime either in the form of grazing and/or product extractions. The researcher also suggests that the pedological differences could also have contributed for the variation in species composition among sites. According to Intermediate Disturbance Hypothesis (IDH), controlled and intermediate disturbances are reported to increase spatial heterogeneity of species provided that other environmental conditions such as nutrients, water, sun light, temperature and other physical and biological factors are favorable (Graham and Duda, 2011). Disturbance has both negative and positive effects on species richness and composition based on its intensity and duration (Pausas and Austin, 2011). A report by Laloo et al. (2006) on medicinal plants in the sacred forests of Meghalaya, Northeast India also shows that species richness varies in disturbed and undisturbed sacred forests.

Each forest site was also found to have different plant community type. For instance, Sideni graveyard is characterized by a community type over-dominated by *Acokanthera schimperi* (1541.6 per ha, 56.32%) followed by *A. negrii* (245.8 per ha, 8.98%). On the other hand, Merma and Gubahil graveyards are largely dominated by *C. edulis* which accounts 725 and 783.33 individual plants per hectare, respectively (Table 2). Overall, it can be concluded that Sideni burial site is apparently dominated by trees, while Merma and Gubahil graveyards are mainly dominated by shrubs. Aerts et al. (2006) also reported that the most abundant and widespread species in Afromontane church forests in the northern highlands of Ethiopia include *A. schimperi, Acacia etbaica*, *Euclea racemosa*, *Justicia schimperiana*, *Leucas abyssinica*, and *Pavetta gardeniifolia*. Other study report by Wassie et al. (2010) on church forests in a fragmented Ethiopian Highland landscape shows that *J. procera*, *O.europaea* and *Maytenus arbutifolia* to be the dominant woody plant species in terms of their

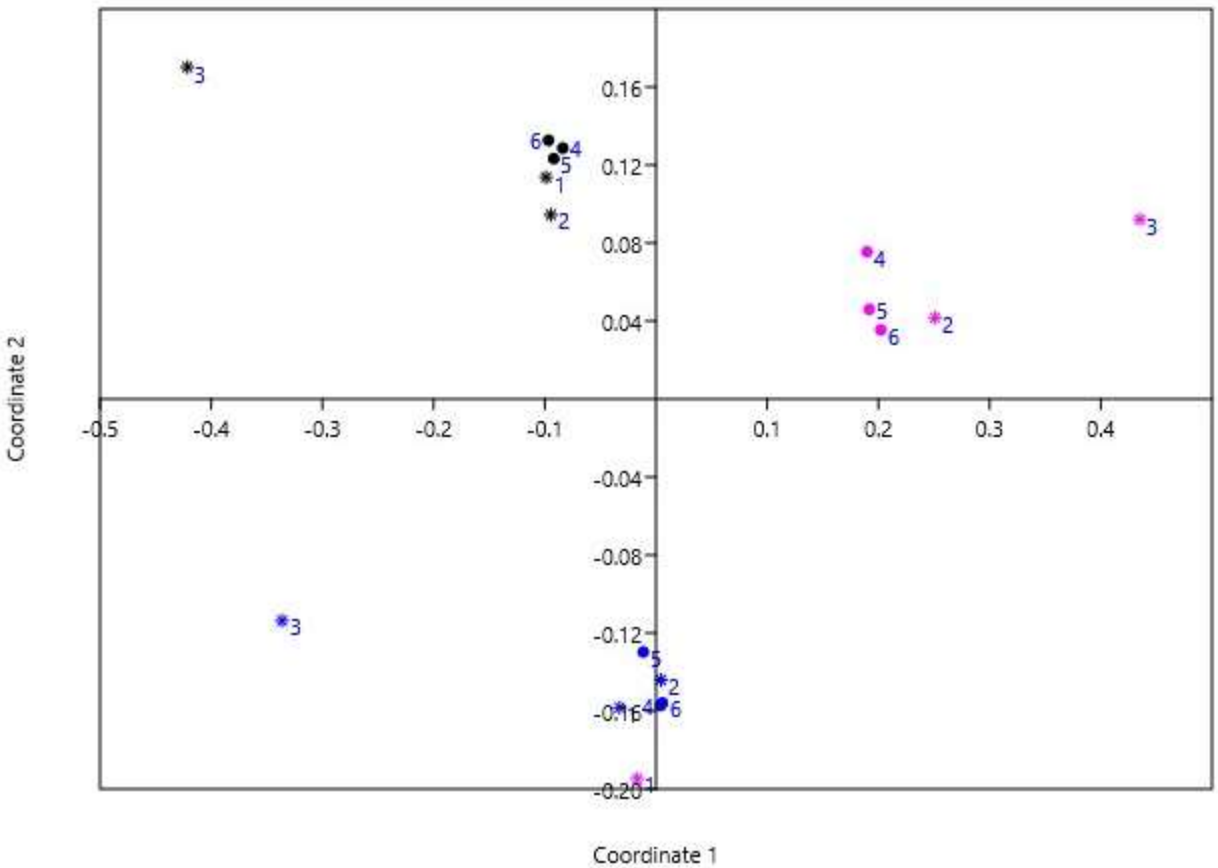

Figure 5. Non-metric multi-dimensional scaling (ordination) indicating the trend of changes in species composition across sampling sites and quadrats (pink=Sideni site, black= Merma site and blue= Gubahil site, and star=edge-habitat and dot=interior-habitats, and 1-6 are quadrat numbers). The different coloration and symbols used are intended to clearly see the position of each sampling site and respective quadrats for their species composition in a 2-D-axis using Bray-Curtis similarity.

importance value in all forests they sampled.

Ecological importance of burial forest sites

The local community has solid awareness and understanding on the local and regional climatic changes and so the importance of ecosystem conservation and management. In this regard, the local government has played an important role in educating the locals about the need of soil conservation and ecosystem restoration. The local community, meanwhile, has witnessed that the vegetation cover in their vicinity had temporally and spatially decreased as the result of deforestation and unwise utilization of forest resources. The local community has a deep-rooted custom of protecting and conserving burial sites for many socio-cultural purposes. Apart from their socio-cultural importance, burial sites in the study area have several ecological values such as refugia (sources and sink) for certain wild animals including Hyena, Fox, Monkey, Porcupine, Gazelle, Partridge, and many other bird, bat and reptile species. Mgumia and Oba (2003) also reported as sacred natural sites serve as key refugia for plants and animal species, and other ecosystem services as well.

A study in west Kalimantan, Indonesia, also shows that sacred forests also serve as burial sites and fruit gardens (Marjokorpi and Ruokolainen, 2003). The socio-ecological and conservation values of sacred forests are also reported by Aerts et al. (2006) in their study on Afromontane church forests in northern highlands of Ethiopia.

CONCLUSION

Implication of burial forests for conservation

Forests are important sources of many life forms including plants, animals and other micro and meso-faunas. But, forests are under high pressure of deforestation and fragmentation as well as encroachment.

Table 2. Abundance, density, relative abundance and relative density of most dominant woody plant species in the study sites. Abundance is computed based on 6 quadrats of 20 by 20 m for each species in each site.

SIDENI			MERMA			GUBAHIL		
(Total spp # 22)			(Total spp # 17)			(Total spp # 15)		
(Total count 657)			(Total count 593)			(Total count 493)		
(Total Density 2737.50 ha^{-1})			(Total Density 2470.66 ha^{-1})			(Total Density 2054.29 ha^{-1})		
Species	**Abundance (%)**	**Density**	**Species**	**Abundance (%)**	**Density**	**Species**	**Abundance (%)**	**Density**
Acokanthera schimperi (A. DC.) Benth. & Hook. f.	370 (56.32)	1541.67 ha^{-1} (56.32)	*Carissa edulis* (Forssk.) Vahl	174 (29.34)	725 ha^{-1} (29.34)	*Carissa edulis* (Forssk.) Vahl	188 (38.13)	783.33 ha^{-1} (38.13%)
Acacia negrii Pic.-Serm.	59 (8.98)	245.8 ha^{-1} (8.98)	*Adhatoda schimperiana* Hochst.	137 (23.10)	570.8 ha^{-1} (23.10)	*Acacia negrii* Pic.-Serm.	64 (12.98)	266.67 ha^{-1} (12.98%)
Carissa edulis (Forssk.) Vahl	45 (6.85)	187.5 ha^{-1} (6.85)	*Pterolobium stellatum* Forssk.	43 (7.25)	179.17 ha^{-1} (7.25)	*Acacia abyssinica* Hochst. ex Benth.	31 (6.29)	129.20 ha^{-1} (6.29%)
Pterolobium stellatum Forssk	33 (5.02)	137.5 ha^{-1} (5.02)	*Jasminum abyssinicum* Hochst. ex DC	27 (4.55)	112.5 ha^{-1} (4.55)	*Premna schimperi* Engl.	25 (5.07)	104.20 ha^{-1} (5.07%)
Jasminum abyssinicum Hochst. ex DC	33 (5.02)	137.5 ha^{-1} (5.02)	*Dodonaea angustifolia* L.f.	23 (3.88)	95.8 ha^{-1} (3.88)	*Rhus natalensis* Bernh.	24 (4.87)	100 ha^{-1} (4.87%)
Rhus natalensis Bernh.	14 (2.13)	58.33 ha^{-1} (2.13)	*Grewia mollis* Juss.	23 (3.88)	95.8 ha^{-1} (3.88)	*Maytenus obscura* (A.Rich.) Cufod.	23 (4.66)	95.83 ha^{-1} (4.66%)

Ethiopian forest cover is currently estimated to be 4 to 5%, most of which is confined in South West of the country. Most natural forest in northern highland part of the country are found in religious sites including monasteries, churches, mosques and graveyards predominantly located in rural areas. Burial sites in the study area are home for many plants that are missing in the larger landscapes of the country.

All burial sites in the study area are naturally regenerated forest patches protected by the local people for many socio-cultural and economic reasons. These burial forest sites provide many services such as livestock forage, medicinal plants, and firewood as well as ecological services in the form of habitat (refugia) for some wild animals: hyena, fox, gazelle, monkey and many birds and reptiles. So, it is vital to put efforts for sustainable conservation and management on burial forest sites as they are important sources of valuable plant species. In the study, the great proportions of woody plant species recorded are noticed to be locally threatened and are extremely less abundant across the surrounding ecosystems. So, to avoid local extinction of these economically and socially important plant species, burial sites can be delineated as an important landscape to protect and preserve these locally threatened plant species. Therefore, conserving plant species in burial sites would help the local community to maintain the socio-cultural and economic services they obtain from the sites as most of the woody plant species recorded are not adequately found outside these burial forest patches.

RECOMMENDATION

Due to the fact that burial forest sites provide many ecological, socio-cultural and economic importances, the following recommendation are suggested for sustainable protection and reservation of plants resources in burial forest sites in the study area: (1) protection and conservation of burial forest sites and conservation of plants should be continued, sustainable and promoted, (2) any forms of colonization of burial sites by alien and invasive plant species should be routinely managed and protected, (3) the local government body and all other potential stakeholders should financially and technologically support the local people for their commitment of protecting burial plant resources, and (4) the local government should acknowledge the culture and the effort made by the local people towards protection burial forests and the resources within it.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest

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