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Full Length Research Paper

Spatial and temporal phytoplankton species diversity in Southern Gulf of Lake Tana, northwestern Ethiopia

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To assess phytoplankton species biodiversity in the Southern Gulf of Lake Tana, water samples were collected twice a month from eight sites for six months, from October 2010 to March to 2011. Data were analyzed and compared with one another using SPSS version 16. There were significant differences between months in phytoplankton species composition ($p < 0.05$). However, there was no significant difference among sites during the study period ($p > 0.05$). A total of 67 phytoplankton genera belonging to nine classes were recorded in the study area. The study showed phytoplankton species diversity is poor in the study area. Absence of significant differences among sites might be because there were similar human impacts in the gulf on a spatial base. In contrast to this, the significant differences among the six months might be due differences in nutrient inputs into the lake and also possibly due to human impact differences on temporal base. To conserve phytoplankton species composition so that it is sustainable at all times and sites, the local people in general and government in particular should avoid some activities on the gulf.

Key words: Algal seasonality, cyanobacteria, Ethiopia, Lake Tana, temporal variation of phytoplankton.

INTRODUCTION

Microscopic phytoplankton accounts for approximately half the production of organic matter on Earth (Daniel et al., 2010). According to Daniel et al. (2010) many phytoplankton declines have occurred in tropical regions. The reduction in numbers or change in species composition of phytoplankton could lead to a reduction in zooplankton abundance. Since the 1950s, scientists have recorded a decrease in zooplankton in the Californian current. Whether this steady decline is attributable to a decrease in primary production or an increase in predation on the zooplankton is not certain (United Nations Environment Programme, 2000).

Threats to Lake Tana have serious implications in environmental and human security in Ethiopia and raise ecological and cultural questions (Eguavoen, 2009). The lake provides livelihoods to over 3 million people living around it and is a significant source of hydro power (World Bank, 2006). It is a contributor to food security, providing water resources for agriculture and livestock, and has a significant fishing industry. Staple crops such as rice, pulses and teff are grown in the watershed, which is home to Ethiopia's unique cattle breed, the Fogera

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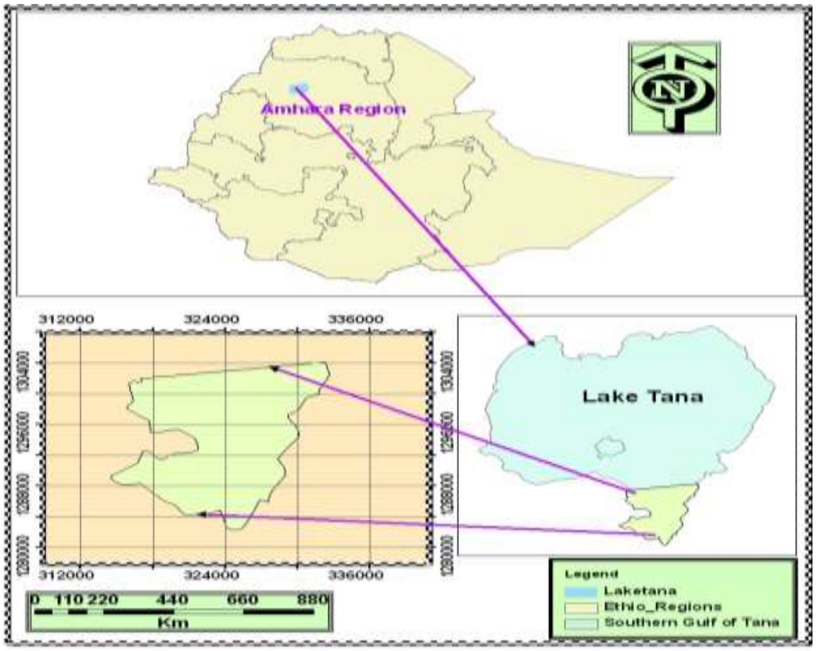


Figure 1. Location map of the study area.

(Abebe, 2008). The lake ecosystem and the water resources as a whole are in danger due to erosion, deforestation, sedimentation, water level reduction, flooding of the wetlands, competing uses of water resources, increased pollution and the pressure of the growing population in its catchment area. There is an erosion of Lake Tana water quality and gene pools affecting the stability and resilience of the system and endangering sustainability of the lake and the surrounding wetland resources (Esthete, 2003).

Many research attempts have been done to describe the chemical, physical and biological characteristics of Lake Tana in general and the southern gulf of the lake in particular. Yirgalem and Assefa (2009) have explained Lake Tana's water level fluctuations annually and seasonally following the patterns of changes in precipitation. Similarly, Akoma and Imoobe (2009) reported on a limnological and phytoplankton survey of the Bahir Dar gulf of Lake Tana but there is no research done on algal species biodiversity done so far in the area. The purpose of this research paper was to determine the phytoplankton species composition on a temporal and spatial basis in the study area, the southern gulf of Lake Tana, Ethiopia from November 2010 to April 2011.

MATERIALS AND METHODS

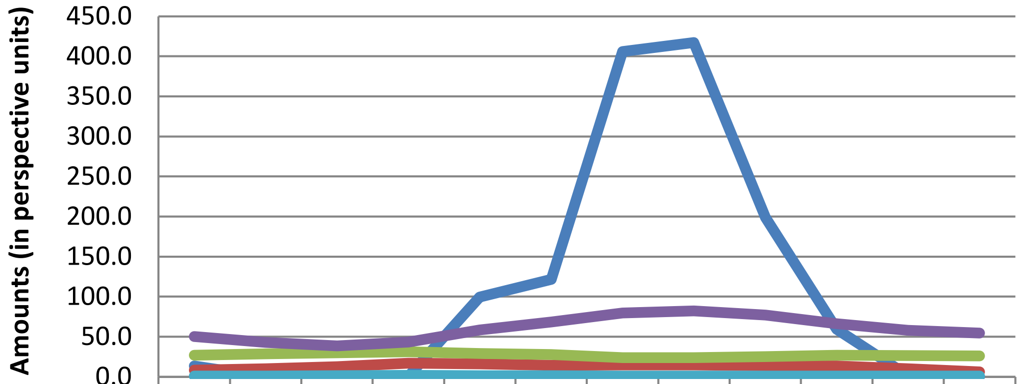
Description of the study area

Lake Tana, situated at an altitude of about 1800 m ASL, is a crater lake formed two million years ago due to the volcanic blocking of the Blue Nile River. Significant inflow to the lake comes from three major rivers (Gilgel Abai, Rib and Gumara) in the south, which carry a large amount of silt resulting from erosion and increase the turbidity of water to the gulf (Berhanu et al., 2001).

Lake Tana serves for local transport, ecological restoration, recreational purposes and dry season irrigation supply (Yirgalem and Assefa, 2010). According to Yirgalem and Assefa (2010), past attempts to observe historical fluctuations of Lake Tana based on a simplistic water balance approach of inflow, out-flow and storage have failed to capture well known events of drawdown and rise of the lake that have occurred in the last 44 years. Bahir Dar town is found on the southern gulf of the lake. According to the Ethiopian Central Statistical Agency (2008), the population living in the town is about 220,000 and is increasing from time to time.

Climate around Lake Tana

The air temperature shows large diurnal but small seasonal changes with an annual average of 20°C. The seasonal distribution of rainfall is controlled by the northward and southward movement of the inter-tropical convergence zone (ITCZ). Moist air masses are driven from the Atlantic and Indian Oceans during summer (June–September). During the rest of the year, the ITCZ shifts southwards and dry conditions persist in the region between October and May. Generally, the southern part of the Lake Tana basin is wetter than the western and the northern parts (Kebede et al., 2005). The climate of Lake Tana is characterized by a major rainy season with heavy rains (June-October). Average annual rainfall in the lake area is 1418 mm. Similarly, the water level of the lake fluctuates with rainfall up to 1 m. Maximum water temperature, as a monthly average, ranged between 21 and 26°C over 1997 to 2000. Water temperatures varied between narrow limits, with lowest values in January, a sharp increase in February, peak values in May and a sharp decline with the big rains in June-July (Esthete, 2003). According to the Ethiopian National Meteorology Agency, Bahir Dar Branch, the maximum and minimum rain fall was recorded in July and August, and in December, February and March in the study



	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Rain fall (ml)	13.3	0.0	0.0	0.6	99.6	121.5	405.8	417.2	199.0	59.4	1.5	0.0
Tmin (0c)	8.4	9.9	12.4	16.7	16.0	14.4	14.7	14.6	14.0	13.4	9.8	5.9
Tmax (0c)	27.0	28.6	29.7	31.0	28.9	27.5	24.0	23.9	25.0	26.7	26.6	25.9
Humidity(%)	50.3	42.9	38.3	43.1	58.6	68.3	79.6	82.4	77.0	66.0	57.8	54.4
Windspeed (m/s)	0.9	0.8	1.3	1.5	1.3	1.1	0.9	0.8	0.8	0.8	0.8	0.7

Figure 2. Main meteorological conditions around study area (2010/2011).

period, respectively. Likewise, the minimum and maximum temperatures were recorded in August and April, respectively (Figure 2).

Site selection and sampling

The sites were selected based on human-induced pressures along the southern gulf of Lake Tana. Site one (Debre Mariam) was characterized by impacts from agricultural inputs. Site two (West Gojam Zone Administration Prison Station) was characterized by human waste inputs. Site three (Shum Abo) was characterized by transportation and recreation around the site. Site four (Titu Recreation Center and port for Tana Transport Organization) was characterized by both transportation and hotel construction on the shore line of the lake. Site five (Bahir Dar City Legislative Area) was characterized by only swimming, washing clothes and bathing. Site six (Mohammed Hussein Ali Al -Amoudi Resort *Area*) was relatively not impacted by humans. Site seven (Felege Hiwot Referral Hospital) was impacted by both human wastes from hospitals and several religious schools. The final site (site eight) (Tana Medhanie Alem Integrated Development Association) was characterized by human-induced impacts from agriculture and lodges. The study sites were named as sites 1, 2, 3, 4, 5, 6, 7 and 8 (Figure 3).

Sampling was done using mesh net (pore size 55 µm) starting from site one to eight in offshore by considering depth and representativeness of the sample for the site as well the gulf and emptied into eight pure sample bottles, for species composition determination. Samples were put into an ice box containing no ice, that is, at room temperature after addition of Lugol's iodine solution (purchased from a local pharmacy). Sampling was done once per month for species composition variation of the southern gulf of Lake Tana starting from November 2010 to April 2011. These samples were transported to the laboratory of Biology Department, Bahir Dar University for species identification and enumeration. The sample reached the laboratory within a maximum of two hours interval after collection and stored at 40°C.

Phytoplankton species composition determination and enumeration

The samples were concentrated following the inverted microscope method (Pxinos and Mitchell, 2000). A 10 L volume of water was concentrated to 100 ml using 50 µm pore plankton net. A sub-sample of 10 ml was taken from this and poured into a 15 ml centrifuge tube and put at room temperature for more concentration following the Utermőhl method for qualitative algal analysis. The 10 ml of water was again concentrated to 5 ml and a sub-sample of 0.1 ml of water was taken using a dropper and one drop of water was put onto an inverted microscope (XDS series Inverted Microscope) slide to identify and quantify the species present. The identification was carried out using various reference books (Fritsch, 1974; Stern, 1997; Elliott, 1974; Botes, *2001*).

Assuming that 0.1ml of water represents two drops, the identified species from one drop were multiplied by two, and to get the number of algal and cyanobacterial species in 5 ml of water, the identified algae and cyanobacteria in 0.1 ml of water were multiplied by 50 following the same logic. Likewise, to estimate the number of algal and cyanobacterial species from 100 ml of water, the previous number was multiplied by 1000; that is, the reverse of the concentration. Then, the species were distributed into their respective classes by site and by time of sample collection.

Statistical data analysis

Spatial and temporal phytoplankton species composition was analyzed through one way analysis of variance (ANOVA) based on total phytoplankton cell counts for all species identified to determine if there were spatial and temporal variations in their abundance, using SPSS 16 software (Statistical Procedures Companion, Maija J. Norušis). Similarly spatial and temporal distribution patterns of the algae and cyanobacteria were converted to percent to compare specific species percentage out of the total phytoplankton community. The mean, range, minimum and maximum abundance of each class were calculated using MS Excel 2007.

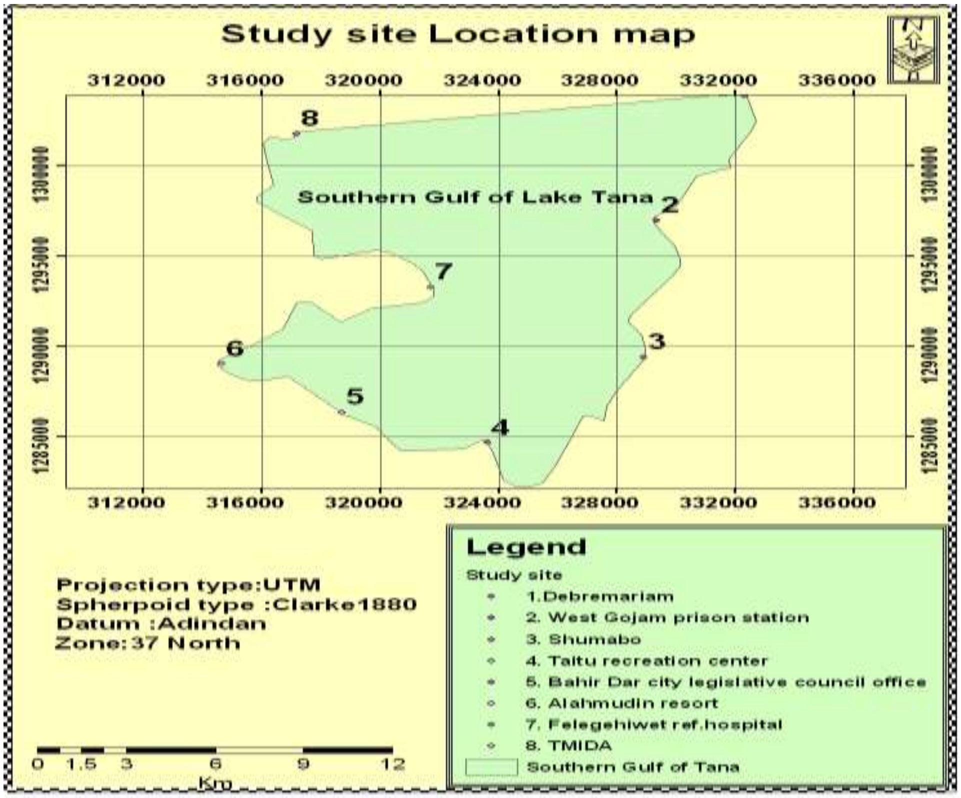


Figure 3. Sampling sites and their names.

RESULTS AND DISCUSSION

Phytoplankton species diversity in Southern Gulf of Lake Tana

A total of 67 phytoplankton genera, in nine classes namely: Bacillariophyceae (17 genera), Chlorophyceae (22 genera), Chrysophyceae (5 genera), Cryptophyceae (1 sgenera), Cyanophyceae (10 genera), Dinophyceae (3 genera), Euglnophyceae (1 genera), Zygnematophyceae (5 genera) and Xanthophyceae (3 genera) were recorded in the gulf. The names of the genera together with their classes are presented in Table 1. There were no significant differences among the months of the study (p-value > 0.05), but, there were significant variations among sites based on cell counts (p-value < 0.05). Figure 4 provides a summary of overall phytoplankton presence at each site and month sampled. At site 1, there was an algal increment towards December and then a decrement towards February and again an increment towards April. At site 2, there was wave like structure where in one month, there was an increment and then a decrement in the next. At sites 3, 5 and 6, there were progressive decrements till March and a higher increment (except site 6) in April. At site 4, there was progressive increment each month relative to the other sites. At site 7, the lowest abundance was recorded in February and remaining months looked similar to each other and had a higher abundance than February. At sites 1 to 5, phytoplankton abundance increased in April. This increment was contributed to mostly by a single phytoplankton class, the Cyanophyceae (comprising more than 60% of the total abundance).

Spatial phytoplankton species diversity

The dominant classes based on abundance (average abundance >350 cells/L) were Chlorophyceae, Cyanophyceae and Xanthophyceae and in some sites, Bacillariophyceae. Bacillariophyceae (commonly diatoms) was neither dominant nor rare; however, it varied from site to site (range from 100 to 500 cells/L) (Figure 5).

Chlorophyceae was present without changing or varying at most sites (sites of 2, 4, 5 and 6). The maximum number of this class and Chrysophyceae was recorded at Tana Medhanielem Integrated Development Asociation (TMIDA) (Site 8) (Figure 5). The maximum number of Chrysophyceae was recorded near TMIDA. Cryptophyceae was the only class that was not ubiquitous in the southern gulf of Lake Tana. It was only recorded at four sites (sites of 2, 3, 4 and 5). The minimum and maximum number of this class were 0 cells/L (sites 1, 6, 7 and 8) and 233 cells/L (site 4),

Table 1. Algal genera and relative abundance of southern gulf of Lake Tana in 2010/11 (where d = less than 20 cells/L, c = between 20 and 50, b = between 50 and 100, a between 100 and 200, a+ = between 200 and 500, a++ = between 500 and 1500 and a+++ = more than 1500 cells/L).

S/N	Taxon	November	December	January	February	March	April
Bacillariophyceae							
1	*Achnanthes*	c	d	d	c	b	a
2	*Coscinodiscus*	d	d	d	d	c	d
3	*Cyclotella*	d	c	c	c	c	a
4	*Cylindrotheca*	d	d	d	d	a	d
5	*Cymatopleura*	d	d	d	d	d	d
6	*Cymbella*	a+	c	b	b	b	a++
7	*Cyanodictilon*	a+	d	d	a	a+	a++
8	*Diatoma*	d	b	c	c	c	c
9	*Fragilaria*	c	b	d	c	d	d
10	*Gophonema*	d	d	d	d	d	d
11	*Hantzschia*	d	b	d	d	d	d
12	*Melosira*	a+	d	d	b	a	a+
13	*Navicula*	d	d	a	a	a	a+
14	*Pseudostaurastrum*	d	d	d	d	d	d
15	*Surirella* sp.	d	d	d	d	d	d
16	*Syndra*	a	b	a	a	a	b
17	*Tabelaria*	c	d	d	d	d	b
Chlorophyceae							
18	*Acculria* sp.	d	d	d	d	d	b
19	*Acetabularia*	d	d	d	d	d	d
20	*Acanthosphaera*	d	d	d	d	d	d
21	*Ankistrodesmus*	d	d	d	d	d	d
22	*Botryococcus*	c	b	c	b	a+	a
23	*Cladophora*	d	c	c	d	d	d
24	*Clamidomonas*	d	d	d	d	d	d
25	*Closterium*	c	d	d	d	d	d
26	*Coelastrum*	d	d	d	d	d	d
27	*Franceia*	a+	a+	d	c	d	d
28	*Entromorpha*	d	a+	a	a+	a+	a+
29	*Kirchneriella*	d	d	d	d	d	d
30	*Mcractinum*	a+	a	d	d	d	d
31	*Planctosphaeria*	d	d	c	d	d	c
32	*Pediastrum*	b	a+	a+	a	a	a+
33	*Pseudosphaerosystis*	d	d	d	d	d	d
34	*Scenedesmus*	d	d	d	d	d	d
35	*Sphaerocystis*	d	d	d	d	d	d
36	*Spirogara*	d	d	d	d	d	c
37	*Stichococcus*	d	d	d	d	d	d
38	*Volvox*	d	c	d	d	d	b
39	*Xanthidium*	d	d	d	d	d	d
Cyanophyceae							
40	*Aphanocapsa*	a++	a++	a+++	a+++	a+++	a+++
41	*Aphanothece*	c	b	d	d	a+	a+++
42	*Aphanozemenon*	c	d	c	a+++	d	a+++
43	*Anabena*	c	a	a	b	d	a+
44	*Coelosphrium*	d	b	d	d	d	b
45	*Cyanodictilon*	d	d	d	d	a	d

Table 1, Contd.

46	***Lingbya***	**d**	**d**	**d**	**d**	**d**	**d**
47	*Microsystis*	a+++	a+++	a+++	a+++	a+++	a+++
48	*Nostoc*	c	d	d	d	d	d
49	*Oscillatoria*	d	a	a	a	d	d
50	*Chrysophyceae*						
51	*Chyrysosphaerula*	a	d	d	d	d	d
52	*Dinobryon*	d	d	d	d	c	c
53	*Epipyxis*	d	d	d	d	d	d
54	*Mallomonas*	d	d	d	d	d	d
55	*Malomonopsis*	a+++	c	c	d	c	a
Dinophyceae							
56	*Glenodinium*	d	d	d	d	d	d
57	*Peridiniopsis*	a	d	d	d	d	d
58	*Peridinium*	a+	a+	a	a+	a+	a+++
Euglenophyceae							
59	*Euglena*	a	b	c	d	c	c
Zygnematophycae							
60	*Coelastrum*	b	b	d	d	d	d
61	*Cosmarium*	d	d	d	d	d	d
62	*Penium*	a+	a	b	a	d	a
63	*Staurastrum*	c	c	a	c	a	a
64	*Staurodesmus*	d	d	d	d	d	d
Xanthophyceae							
65	*Bumilleriopsis*	d	d	c	d	d	d
66	*Goinchloris*	a	b	b	b	b	a
67	*Tribonema*	a+++	a+++	a+++	a	a	a

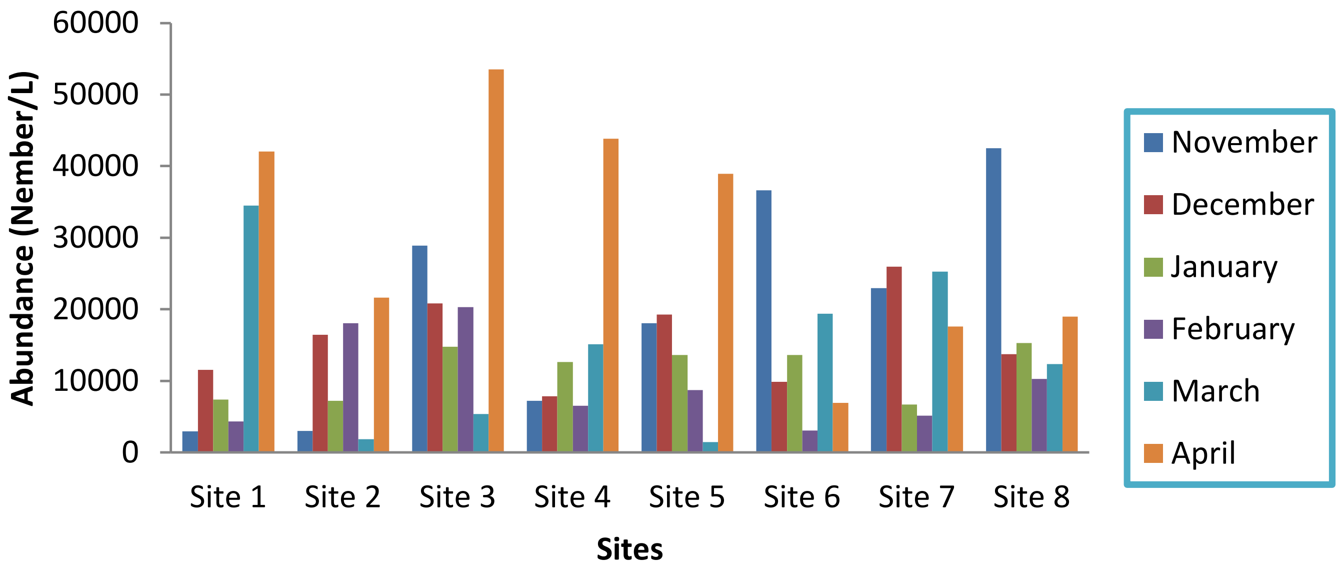


Figure 4. Phytoplankton distribution and abundance in the study area for November 2010 to April, 2011.

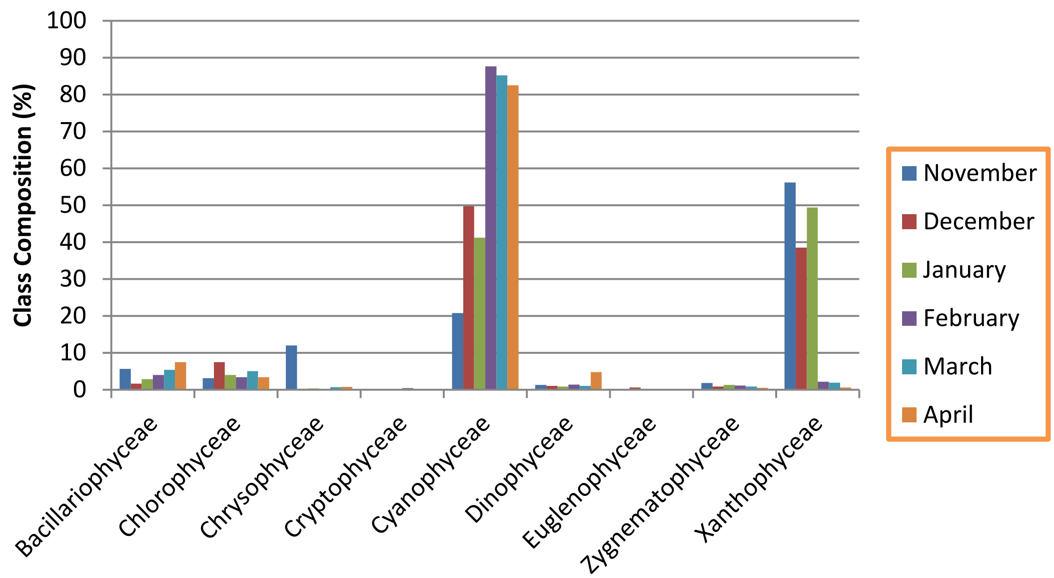


Figure 5. Temporal phytoplankton class composition in the study area (November 2010 to April, 2011).

respectively (Figure 5).

The most dominant class in study area by cell number count was Cyanophyceae. Variations in this class were observed at most sites, except at Taitu Recreation Center (site 4). The minimum and maximum numbers of cells/L were recorded at Shum Abo (site 3) and at West Gojjam Prison Station (site 2), respectively (Figure 5). Similarly, the maximum abundance of Class Dinophyceae was recorded near Debre Mariam (Site 1). Relative to other classes, this class was constant in all sites throughout the study periods (Figure 5).

The most dominant class in the study area was class Cyanophyceae. Variations in this class were observed at most sites except at Taitu Recreation Center (site 4). The minimum and maximum numbers of cells/L were recorded at Shum Abo (site 3) and at West Gojjam Prison Station (site 2), respectively (Figure 5). Similarly, the maximum abundance of Class Dinophyceae was recorded near Debre Mariam (Site 1). Relative to other classes, this class was constant in all sites throughout the study periods (Figure 5).

Class Euglenophyceae was not found near Shum Abo (site 3), Taitu Recreation Center (site 4) and Bahir Dar City Legislative Council Office (site 5). The highest and second highest presence was recorded near Felege Hiwot Referral Hospital (site 7) and TIMIDA (site 8) (Figure 5). The second least dominant class in the southern gulf of Lake Tana was the Class Zygnematophyceae. Relatively, the least variations were observed near Debre Mariam and Shum Abo. The maximum cell number of this class was recorded at TMIDA (Figure 5).

The least dominant class in the study area was Xanthophyceae. However, it was persistent throughout the six months of assessment. Its dominancy ranges from nil (sometimes) to third dominant on other occasions. It was counter partner of Cyanophyceae in abundance which means that Xanthophyceae increased and Cyanophyceae decreased (Figure 5).

Temporal phytoplankton species diversity in South Gulf of Lake Tana

In this gulf, the algal classes of Bacillariophyceae and Dinophyceae were almost constant throughout the 6 months of study period of in 2010/11 having the highest prevalence in March and April and the lowest prevalence in December and January respectively. Cryptophyceae and Euglenophyceae were very low in all the months. Class Cyanophyceae presence increased progressively from November to February and became constant in March and April even though it slightly increased in April (Figure 5).

The detailed information on each class for all months is presented separately. Bacillariophyceae was a generally persistent class. Generally, this class was relatively higher in November and April. In April, it was sometimes second and third most dominant class in the southern gulf of Lake Tana. The minimum and maximum cell numbers of this class were recorded in December and April respectively.

Chlorophyceae presence varied from two peaks in November and April and its lowest abundance in February. It gradually decreased from November to February and then gradually increased from February to April. Usually outliers were common in terms of this class in the months of November, December and March.

Similar to Chlorophyceae, the maximum abundance of Chrysophyceae was recorded in November and April. In contrast to Chlorophyceae, it neither decreased nor increased in between these two months which means it was constant from December to March even though outliers were common in February and March. There were almost nil Cryptophyceae in the southern gulf of Lake Tana. It was only recorded in January and February. The range of variation on this class ranged between zero (in November and December, March and April) and 234 cells/L in February.

Cyanophyceae was, as in its spatial distribution described above, dominant throughout the 6 months of study period in the southern gulf of Lake Tana. It gradually increased from November to December and again decreased in January. It then increased from January to April (maximum abundance in February). Dinophyceae was constant throughout the 6 months study period. This class can be divided in to two on a monthly basis: relatively higher abundance and lower abundance months. November and April were the months when the maximum growth of Dinophyceae was recorded. The remaining months were constant and slightly lower growth of Dinophyceae was observed. The highest abundance in Dinophyceae was recorded in April, 2011 relative to the remaining months.

Euglenophyceae and Cryptophyceae had a similar distribution and abundance in the southern gulf of Lake Tana. Both of them had a low abundance and were found at some sites and months of the phytoplankton assessments. The 6 monthly minimum and maximum abundances of Euglenophyceae were in November and December of 2010, respectively.

The Zygnematophyceae attained the minimum cell counts in March and maximum cell counts in April, respectively. Relatively, this class fluctuated from month to month. Xanthophyceae were opposite to Cyanophyceae in their dynamics and structure in the phytoplankton community of the southern gulf of Lake Tana. The maximum abundance of this class was recorded in November and decreased in December. It then increased from December to January and again gradually decreased in April.

DISCUSSION

According to Talling and Heaney (1988*), the* dominance of phytoplankton species in water bodies is determined by complex interactions between biological, physical and chemical variables. In the southern gulf of Lake Tana, Xanthophyceae was the dominant class in November and it presence slowly decreased to April. This may be due to grazing by fish and competition from Cyanophycae for resources at the same time as nutrient loads in water inflow to the lake from various sources within the catchment decreases. Fish production, for example, is low in early summer (Tesfaye, 1998). Nutrient loads due to run off into the lake are high in the summer season (June-Sept) and low for the rest of the year (Yirgalem and Assefa, 2009). In contrast to this, Cyanophyceae consequently increased from November to April. This may be due to taste and odor of compounds and perhaps toxins may deter grazers, so that it cannot be eaten mostly by grazers.

As reported by Shapiro (1997), the ability of cyanobacteria to use bicarbonate as a carbon source is one of the reasons for their dominance in alkaline aquatic systems. This could be applied for the southern gulf of Lake Tana, which has an average pH of 6.83 to 8.3 (Eshetye, 2003). In this study, it was found that at almost all sites, the dominant phytoplankton species were *Microcystis* (cyanobacteria), *Tribonema*, *Aphanocapsa*, *Peridinum* and *Cymbella* species. This might be bicarbonate sources in the gulf.

Swimmers have reported rashes, hay fever-like symptoms and even pneumonia associated with blue green algae blooms and their toxins (Fleming and Stephan, 2001). According to Fleming and Stephan (2001), abdominal cramps, nausea, diarrhea and vomiting may occur if the swimmer swallows the untreated water. Even water-skiing, showering or cleaning with this water may make people sick because the toxins may be absorbed from water breathed into the nose. Unfortunately, boiling water does not remove or destroy these toxins (Fleming and Stephan, 2001). Similarly, those people swimming in the southern gulf of Lake Tana, if inflows of untreated sewage and other untreated runoff occur, they could be subject to a lot worse disease and gastrointestional problems. In addition, the dominance of single class Cyanophyceae may be there is imbalance in species diversity in the study area.

Conclusions

Incidents attributed to cyanobacteria are far more numerous and, in most cases, have been caused by species of cyanobacteria that may accumulate as surface scums of extremely high cell density. As a result, the toxins they contain ("cyanotoxins") may reach concentrations likely to cause health effects (World Health Organization, 2000). In the southern gulf of Lake Tana, the phytoplankton species diversity is poor. However, there was a very high density of cyanobacteria. Cyanophyceae species can cause severe problems to the people living around the gulf, especially swimmers and people drinking untreated water from the lake.

Different factors can influence the growth of phytoplankton resulting in the dominance of different phytoplankton taxa. There was a significant difference in phytoplankton species composition in the southern gulf of Lake Tana. Thus, there might be human impacts that makes some phytoplankton to be dominant (*Microsystis* sp. and *Tribonema* sp.) and some others which have low abundance or sometimes not present at all.

Absence of significance differences among sites might be due to a possible similarity in anthropogenic impacts at all sites around the southern gulf of Lake Tana or that the gulf is well mixed so that impacts become more widely and evenly dispersed across the gulf. The presence of significance variations between the monitored months in terms of phytoplankton abundance showed that there were very high anthropogenic impact differences from time to time in gulf or simply seasonal effects especially inflows.

RECOMMENDATIONS

During the study period, there were many constraints regarding resources (finance, apparatus and man power, especially skilled man power). If these constraints were absent in the study, there might be at least 100 phytoplankton species identified. Therefore, there is a need for more work to be done in the southern gulf of Lake Tana to accomplish the target objectives. In the gulf generally and Felege Hiowt Referral Hospital and West Gojjam Prison Stations areas in particular, there was reckless use of the gulf by adding waste and hence nutrients may increase which is favorable for a few species to become dominant. Hence in future work, there would be a better opportunity for removing inputs (pressures) from areas surrounding the gulf ecosystem. Such work can include policy, decision and plan making and thus bring sustainable growth and protection of the aquatic biodiversity and resources of the gulf for future generations.

Since the gulf receives nutrients from the inflow rivers during the flood season and contaminated runoff from various sources like the hospitals and prison stations, there is a need to balance, remove or at least minimize the hydrological changes. It is better, for Bahir Dar City people in general and for individuals who use water of the gulf in particular, to avoid drinking, cooking or bathing with untreated water from the gulf.

Conflict of Interests

The authors have not declared any conflict of interests.

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The prevalence and impact of coffee arthropod pests in the gedeo indigenous agro forestry systems, Southern Ethiopia

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Coffee crop has been contributing a lion share to the Ethiopian economy. Despite of its economic significance, it suffers from many production constraints, of which arthropod pests influence both the yield and quality of coffee. The study was aimed to assess the prevalence of arthropod pests and indigenous management across two agro-climatic zones, in the Gedeo agroforestry systems. Twelve farmscapes were randomly selected from the two agro climatic zones. From each farmscape, samples were taken from traditional and improved coffee fields. On each site, two quadrats of 10 m × 20 m plots of coffee fields were sampled to assess the presence/absence of pests and / or damage symptoms, the number of pest arthropods and the damage level per coffee tree for determining the pest prevalence. The number of pests per plant was subjected to SPSS ver.20 statistical software, and the pair wise comparison was computed to compare each study sites. The result indicates that the three top prevalent coffee pests were coffee berry borer (*H. hampei*), coffee white stem borer (*A. leuconotus)*, and Serpentine leaf minor (*C. alertreuta*). However, there is no significant difference on pest prevalence among the agroclimatic zones. Although disease incidence was very high across the study sites, the highest incidence was recorded in Gololcha *kebele* (82%), of Kochore district. In all cases the level of infestation was below standard, and coffee arthropod pests do not seem to be serious major problems responsible for the coffee production loss. Yet, we recommend multi seasonal and multi temporal data to arrive to the conclusion about the pest status of the study area.

Key words: Arthropod pests, coffee berry borer, damage level, farmscape, Gedeo.

INTRODUCTION

Coffee (*Coffea arabica* L.), which is thought to have originated in Ethiopia, is the backbone of the country's economy (Mesfin Ameha, 1991). Ethiopia contributes a total of 7 to 10% coffee induction to the world (FAO, 2010). In Ethiopia, about 20% of of the population depend on coffee for their livelihood which accounts for 35% of the total export earnings (Berhanu et al., 2013). About 70% of which is produced as garden coffee.

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Garden coffee is cultivated and produced in the homegardens of small-scale subsistence farmers, and is a low input-output crop in the southern and southeastern parts of the Ethiopia, with plots of varying size (usually < 0.5 ha) around farmers' dwellings and predominantly intercropped with a variety of fruit, root and cereal crops (Girma et al., 2008).

Although 103 species of *Coffea* and seven infraspecific taxa–have been recognized worldwide (Waller et al., 2007), only two are economically important. Coffee (*Coffea arabica* L. and *C. canephora* Pierre ex A. Froehner) is the world's most valuable tropical export crop, with an annual retail value of approximately US $90 billion (ICO, 2011). *C. arabica i*s preferred to coffee species due that it is taken as superior quality for its taste and organic nature (Fuad, 2010). Arabica coffee offers superior cup quality and aroma compared with Robusta, which commonly owns a more aggressive flavor and, in light roast coffee, has a flat popcorn-like aroma which is responsible for approximately 70% of the global coffee market. *C. arabica* prices have increased by 160% during the past years (ICO, 2011) that is related with production shortages, small farm size, lowest-ever world market prices due to increasing temperature and consequent damages , among other reasons (Jaramillo, 2011).

Coffee production is constrained by copious factors (both biotic and abiotic), including losses due to damage by pests and diseases, poor management practices, soil infertility, and poor pricing. Poor price of coffee is also associated with the damage caused by pests, particularly insects that are proliferated by the climate change. Thus, with the current climate change it seems rational to evaluate the status of insect pests meant to sustain the management of coffee plantation. The incidence and spread of pests and disease are also likely to increase and affect crop yields and quality. For instance, the proliferation of the coffee berry borer, the world's most important coffee pest, in East Africa and parts of South America is predicted to push arabica production to higher areas where the pest do not flourish (Jaramillo, 2011). Insect pests are among a number of factors that contribute to low yield. Greater than 45 insect pests were reported in coffee fields from Ethiopia (Million, 2000). Some insect pest species such as Antestia bugs, and coffee leaf miner, *Leucoptera caffeina* (Washbour) are considered as major insect pests of coffee particularly in larger farms. Coffee berry borer, *Hypothenemus hampei* (Ferriere) is a potentially important insect pest of coffee in Ethiopia (Girma Adugna, 2008). Losses due to coffee pests are estimated to be 13% worldwide (Nyambo and Masaba*,* 1997). The yield loss due to some insect pests such as Anthestia bug was reported to be 9% in Ethiopia (Girma, 2008).

Over the past 3 to 4 decades, changing climate, particularly global warming has already produced numerous shifts in the distribution and abundance of many species. Climate change and invasive species are considered as two of the most important ecological issues facing the world today (Ward and Masters, 2007). Drought and warm climate condition, and irregularity of rain were suggested as means to have caused pest outbreak in Gedeo agroforestry (Abdu and Tewodros, 2013). The changes in climatic conditions are predicted to profoundly influence the population dynamics and the status of agricultural insect pests and as temperature has a strong and direct influence on insect development, reproduction and survival (Ward and Masters, 2007). The impact of insect pest problem is pronounced more in intensive coffee production system than coffee in traditional home gardens and semi forest coffee since such systems could have long traditional and culturally associated protection practices (Million, 1987).

Furthermore, a study from Sidama, Ethiopia showed that less susceptible to disease and insect pests, better economic and market related issues, growth under broad climatic conditions, tolerance to drought for long periods caused farmers to prefer khat to coffee cultivation (Gessesse, 2007). Gedeo Zone is one of the major coffee growing areas at altitudinal range of 1500 to 1800 m asl, which requires special attention for its peculiar floral quality of the agroforestry system (FAO, 1998). The organic coffee is grown under shade that covers 47% of the total land in Gedeo that supports more than one million of the people (GRADAO, 2010). However, the status of coffee production with respect to insect pests in Gedeo agro forestry is not well known. Thus, this research seeks to find methods to manage insect pests and related disease, improve coffeee production among smallhodler farmers and sustain productivity; the type of insect pests need to be identified and management option has to be forwarded, among other factors. The current study was aimed to assess the diversity of existing arthropods and other pests, and to examine the level of damage among coffee landraces across different agroclimatic zones.

The general objective of the study was to assess the prevalence of arthropod pests and others, their management across agro-climatic zones, in Gedeo agro forestry system, SNNPR, Ethiopia whereas the specific objectives of this study were to assess for the diversity of existing arthropods and other pests on coffee plant in Gedeo agro forestry system; to identify the level of damage between varieties and land races in relation to pests' population and their indigenous management options, and to estimate the implication of the influence that pests could cause on the production and productivity of the coffee in Gedeo zone.

Description of the study area

The Gedeo Zone with a total area of 1,347 km^2 and an altitude range of 1,350 to 3,000 m asl, stretches along the main highway from Addis Ababa to Moyale (located

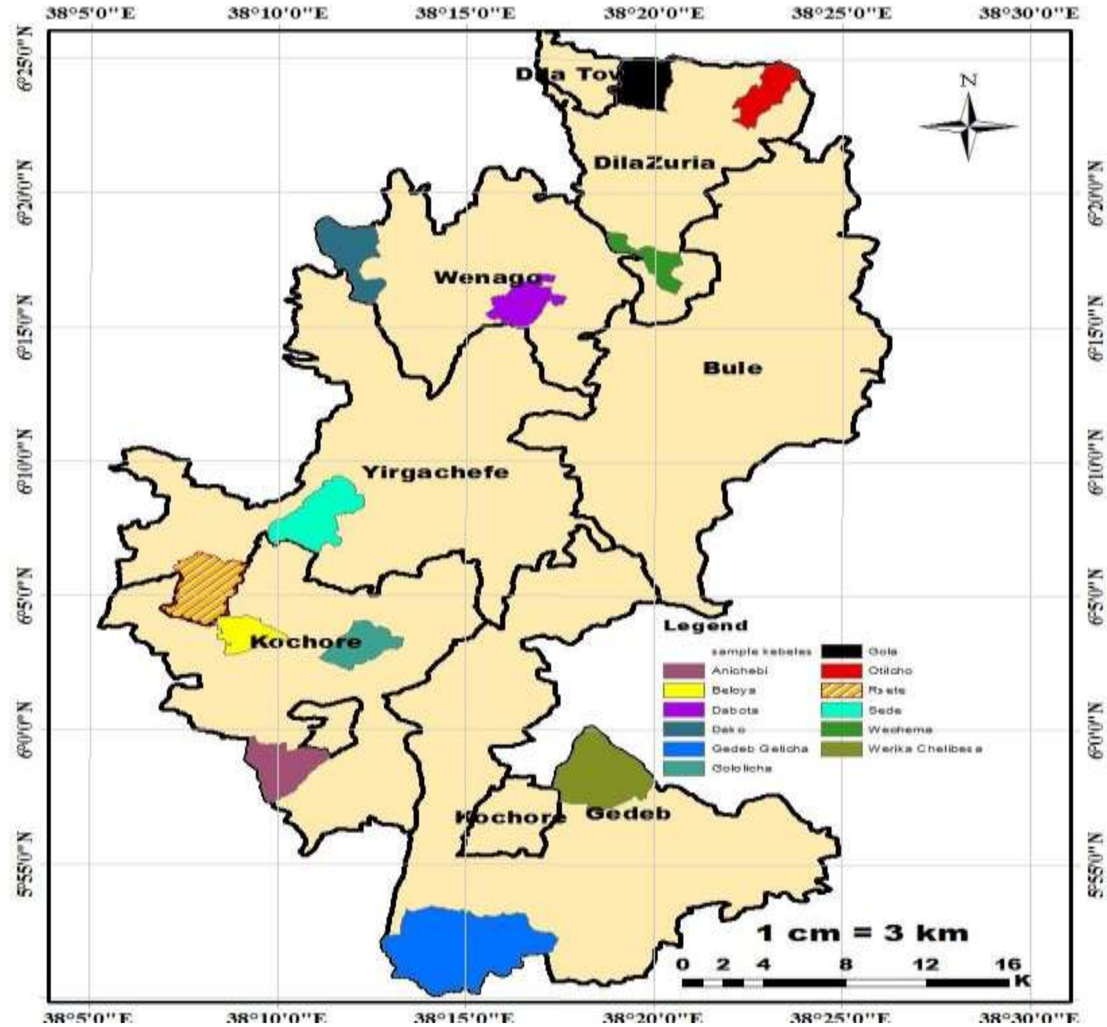

Figure 1. Map of the Gedeo zone, Southern Ethiopia.

about 360 km away from Addis Ababa or 85 km away from the Regional Capital, Hawassa). The study area includes all the coffee growing farmscapes of Gedeo Zone, Ethiopia (GZARD, 2015). Agroecologically, Gedeo Zone covers 70% *Woina Dega*/mid altitude that ranges from 1800 to 3200 m asl, 28% *Dega* (high land, 2400 to 3200 m asl), and 2% *kola* (lowlands, 500 to 1800 m asl,) (Daniel, 1977). Figure 1 indicates the map of sample *kebeles* (lower administrative units). Geographically, the Zone is located North of Equator from 5° 53'N to 6° 27'N latitude and from 38° 8' to 38° 30' East,longitude (Figure 1).

METHODS

The approach for this study involved mixed qualitative and quantitative methods. The study was carried out in a three-stage process as follows: The first stage involved designing the methodology and piloting of zonal mapping of the coffee producing areas. The mapping was designed to identify key agents and stakeholders and to develop hypotheses for carrying out the household survey. The second stage involved conducting the household and field survey on coffee producing areas. Finally, the third stage involved gathering information from a meeting with key informants to pinpoint on the specific problems and the existing pests and their status.

Source of data

The study was conducted to collect data only from primary sources (original data collection) and the other is a review of existing literature. Quantitative data were collected from 180 households and nearly 50 in-depth key informant interviews from May 2014 to October 2014, with the objective of uncovering interests and incentives of various relevant actors to the sector. Samples for the households were drawn from representatives of coffee producers in their respective kebeles. The data collected include socio-economic aspects of the households, coffee landraces, constraints to coffee production, coffee pests and their effects, and indigenous management of coffee.

Data collection tools

For data collection, both questionnaires and semi-structured interviews were arranged which was translated to the local language (Amharic and Gedeoffa) for the sake of clarity. In addition, direct observations of the coffee shrubs in the selected sites per kebele were done.

Sample collection

The five woredas were characterized by differences in type of coffee grown, holding size and method of cropping. At higher elevations, where disease incidence, and therefore, cost of production is higher, coffee has been neglected or uprooted to a far greater extent than in lower elevations. Twelve farmscapes from two main agroclimatic zones of coffee producing areas, namely *Woyna, Dega* and *Kolla* were randomly sampled. Farmscape is a landscape in which farming has largely performed and does play a large role. From each farmscape, two sites one from indigenous traditional coffee landraces and other from improved coffee landraces (Serto Masaya) were deliberately selected. Two quadrats of coffee field (10 m × 20 m), each was sampled to assess the varieties of coffee (landraces), presence /absence of any sort of pests (arthropod) and / or damage symptom. The age of the sample coffee landraces used for the study was ≥ 5 years. The target population for sampling was coffee growers rather than general pool of famers. The survey was used to benchmark yields reduction due pests and adoption of improved practices for assessing the impact.

The number of pest organisms, and/or damage per parts of the coffee plant was taken as parameters to determine the pest status or load was determined as major (1), potentially important (2), and minor pests (3) following (Esayas and Chemeda, 2007). Coffee landraces were examined for production and resistance to pest organisms. The observed pests were collected to plastic bags with some parts of the coffee plant to serve as a food for some times until the species identification. Then, the collected pests were identified using the identification keys in the Entomological Laboratory of Dilla University. One hundred eighty farm households were selected to gather data on the indigenous pest management using questionnaires. Furthermore, fifty key informants were interviewed to gather the data on indigenous knowledge of the pest management.

Surveillance conducted

The researchers conducted detection, delimiting and monitoring targeted places and parts, trackback and track forward, and sentinel site surveys, for any of the pests. The detection was conducted to determine whether the pest is prevalent in a defined area where it is not known to occur before. This was very broad in scope since the pest surveillance was done over large areas to examine the coffee damage, and symptoms by the suspected pest species on the seed, leaf, stem and root areas. Statistically, a detection survey is not a valid tool to claim that a pest does not exist in an area even if the results are negative. Negative results can be used to provide clues about the mode of dispersal, temporal occurrence, etc. Negative results are also important to compare results with sites that are topographically, spatially, or geographically similar (Roger and Wilson, 2009).

Survey procedures

The following tools were used singly or in any combination to detect the presence of insect pests and others. Coffee shrubs were of other potential host plants, and nearby resting places for adults. Disturbing plants to provoke the flight of adults and collection of samples of insects while inspecting potential host plants or plant part is a must. High risk areas where the pest is more likely to be found was focused on and regular sites were established to inspect along the normal surveying route following Roger and Wilson (2009).

Since pests are found attacking nursery stock, surveyors compiled list of facilities associated with the nursery stock infested with pests. Sweep-net and areal nets were used to collect adult samples. Therefore, for all the surveillance roving survey was employed to assess pest population and the damage they inflict following Pedigo and Rice (2006). The relative measure of insect damage was determined as follows: The damage status was considered as:

1. Low if pest population is one to two per coffee plant
2. Moderate if population is three to five per coffee plant
3. High if population is five insect per plant, and
4. Severe if it is above five.

Identification of farmers' indigenous management practices

Semi-structured interview was used to collect data on coffee production, challenges and indigenous pest management practices. Questions were directed to provide an indication of farmers' perceptions and knowledge, decision-making indicators related to pest management strategies. The economic injury level (EIL) is the method used to determine when an insect (or any other organism) becomes a "pest," so that management (ecological or otherwise) needs to be undertaken for the simplified way of illustrating when an insect becomes a pest as stated by Rechcigl and Rechcigl (2000). The most frequently used equation to determine the economic injury level (EIL) is:

$$EIL = C \div VIDK$$

Where: C = management costs per production unit (e.g. \$/ha), V = market value per production unit (\$/kg), I = injury per pest equivalent, D = damage per unit injury (kg reduction/ha/injury unit) and K = proportional reduction in injury with management (Pedigo et al., 1986).

For practical field use, the economic threshold (ET) is generally recommended which is the pest density at which control action should be taken to prevent the pest population from reaching or exceeding the EIL (Pedigo and Rice, 2006). During the assessment for the prevalence of disease in the area; the disease incidence formula was employed using:

$$Disease\ Incidence = \frac{Number\ of\ Infected\ Coffee}{Total\ Number\ of\ Coffee\ Tree} * 100$$

Data analysis

Different methods of data analysis have been employed in this study depending on type of data and the methods of collection. Both descriptive and inferential statistical methods were used. SPSS Ver. 20 was used to compute ANOVA (P<0.05).

RESULTS

Background of the informants

Seventy percent of the informants were males, and the

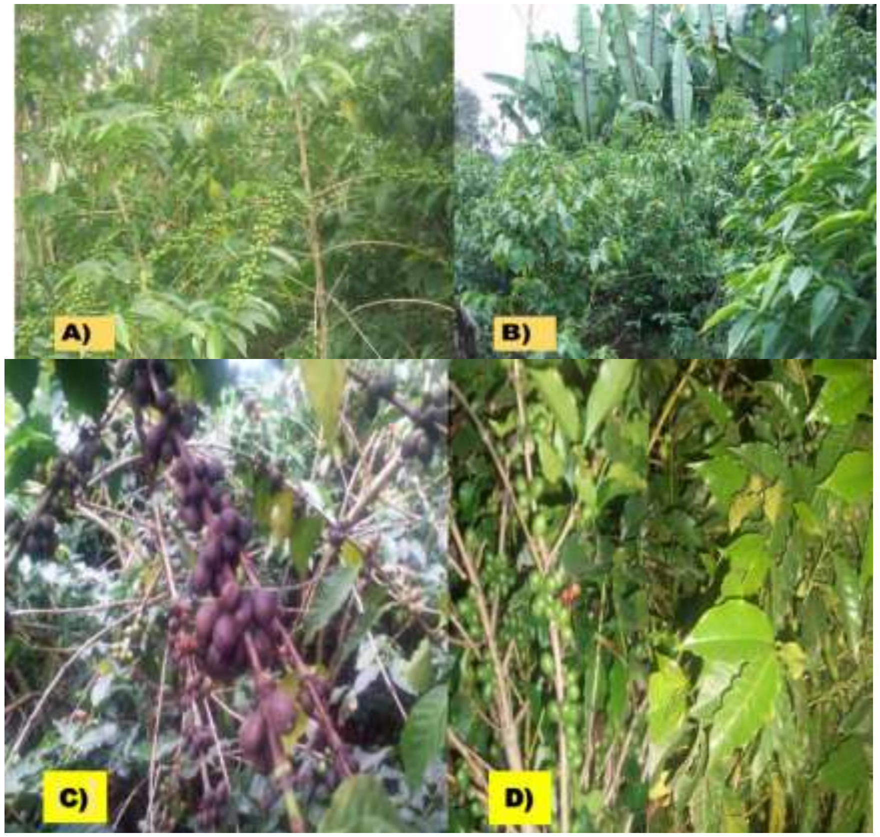

Figure 2. Some of the coffee landraces: (A) Serto, (B) Wolisho (C) Dega and (D) Wolisho infected.

average age of the informants was 47 years with a range of 35 to 92 showing that the informants had long experience of growing coffee crop. About 85% of the informants were able to read and write (average grade level, 6.2 ± 2.4, mean ± SD), which also indicates the fertile ground that someone can transfer an appropriate adoption technology for the improvement of coffee production. The studied households (HHs) with the mean family size and labor force of 8±2.1 and 4±1.3, respectively shows the presence of adequate human capital to grow and manage coffee field. The study population had an average land size of 0.53 ha and only 11% of them had off-faring activities, mainly trading. The annual mean income of the households was 5874 ± 530 (Ethiopian Birr), which is lower than the annual mean income of the country (currently > 10000 birr). These figures show the higher density of coffee farming households with limited resource availability could decline the production quality as well as the quantity of coffee crop.

Coffee landraces and the ecosystem services

The current study has identified four main coffee landraces under arabica coffee, based on some morphological characters (e.g., ripen berry color, berry size, flavor/taste, productivity, resistance to drought and /or disease), leaf size and apical leaf color) as well as informants confirmation. Of the common landraces recognized, the first three are locally accepted accessions, namely *Kurumie* (compact with small leaves and small sized berry), Wolisho (large leaves and bigger berry), Serto (improved variety named after the Amharic name '*Serto Masaya'* to mean certified for demonstration to the users), and *Deiga* (the intermediate between *Kurumie* and *Wolisho*) (Figure 2).

There are many certified varieties (serto types) distributed from Ethiopian Agricultural Research Institutes. The following are among the improved varieties which are popular and currently being used by local farmers like 94110, 74112, 74158, 741 and 744**.** Kurmie and Wolisho are old farmer varieties, which hold the largest proportion while the improved variety types were not grown commonly by all households because they were more recently introduced by District Agricultural Office against diseases such as coffee berry disease which is endemic to east Africa (Figure 2D). According to informants, all the landraces were almost equally subjected to ecosystem disservices except pathogens. Fungal pathogens (not

Figure 3. Land races: (A) Serto; (B) Wolisho.

covered in this study), mainly the coffee berry disease caused by *Colletotrichum kahawae* affected Wolisho variety more than Kurumie > Diega > Serto (Figure 3). The ecosystem disservices are the conditions and processes through which natural ecosystems and species reduce productivity or increase production costs. Crop pests investigated in the current study include herbivores, frugivores (fruit eaters), seed-eaters, and pathogens (e.g., fungal), which act as agents of ecosystem disserves.

The local people of Gedeo Zone reported that the ecosystem disservices are caused by *Choroqa* (mealy bug) which is the pest on the coffee root, *Hanjame* (green snake) which sucks coffee berry juice on aerial parts of coffee shrub, *Gindi adrik* (coffee white stem borer), *cia*, (birds) and rats (*lema'e*), and other vertebrates like monkeys and baboon. These organisms affect coffee production quality/quantity in different ways. Furthermore, parasitic plants like dodder, Loranthus, and other epiphytic plants like mosses and ferns were found on older coffee shrub branches. These species were found decreasing the quality of coffee productivity (Figure 4).

Pests recorded

During field survey in Gedeo indigenous agroforestry system, the insect pests most frequently encountered in all the selected localities are clearly identified and listed in Table 1. A lot of insects were observed on the green coffee berry and the damage caused was estimated by collecting sample injured and damaged coffee berry, leaves and branches. The pest status was calculated based on their load per coffee tree (Table 1) and the estimated damage pests inflict is depicted in Figure 5.

The major pests of coffee include boring beetles, scale insects, mealy bugs, other Hemiptera including anthestia, Lepidopterous miners and defoliators, nematode worms, mites weeds and others like slugs, snails, birds and mammals. Every part of the coffee shrub, that is, roots, stems, leaves, flowers, berries and the seed in storage can be attacked by insects and other pests in coffee growing areas.

The result indicated that there was statistically insignificant difference in the damage of coffee plant by various pests (P>0.05). However, the highest, severe level was recorded by coffee berry borer, *Hypothenemus hampei* which is the world's worst coffee pest (Figure 5). Other arthropods and nematode worm populations were found to be below economic injury level, that is, the damage that this organism caused on coffee plant was insignificant (Figure 5). Nonetheless, the relative damage of major insects was the least on improved varieties (Serto) than local variety called Kurmie (Table 2). All the arthropod pests and others observed on the coffee shrubs were recorded and compared among and between the sampled sites (Figure 6). There was no significant difference among sites (P>0.05). However, coffee berry borer and nematode worms revealed significant difference in terms of disease severity among the average number of observed pests (P<0.05).

The damage measured differs from species to species. For instance, the damage caused by coffee berry borer and coffee white stem borer outweighs the other pests as

Table 1. The list of insect pests of coffee recorded in Gedeo zone, Ethiopia.

Scientific name	Common name	Family	Pest status
Antestiopsis sp.	Anthestia bug	Pentatomidae	1
Anthores leuconotus Pascoe	White coffee borer	Cerambycidae	1
Archips occidentalis Wals.	Green tortrix	tortricidae	3
Ceroplastes brevicauda Hall	White waxy scale	Coccidae	2
Ceratitis capitata Wiedemann	Mediteranian fruit fly	Tephritidae	3
Coccus alpines De Lotto	Green scale	Coccidae	2
Cryphiomystis alertreuta Meyric	Serpentine leaf minor	Gracillaridae	3
Diarthrothrips coffeae Willams	Coffee thrips	Thripidae	2
Hypothenemus hampei Ferriere	Coffee berry borer	Scolytidae	2
Leucoplema dohertyi Warren	Coffee leaf skeletenizer	Epiplemidae	3
Leucoplema caffeine Washboum	Coffee bloch minor	Lyonetiidae	1
Stictococcus formicarius Newstead	Coffee cushion scale	Stictococcidae	2
Toxoptera aurantii Boyer	Coffee aphid	Aphididae	3

*****Status: 1, major; 2, potentially important; 3, minor pest; if (1-2 insect/plant) – low, if (3-5 insect/plant) – moderate, 5 – high and if (> 5 insect/plant) – severe in damage.

Figure 4. Parasitic and epiphytic plant species growing on coffee shrub decresasing its quality : A/ parasitic dodder (*Cuscuta sp*) , B/ parasitic *Loranthus species* , C/ mosses sp , and D/ Fern species

a single insect can lead the whole branch die back or leads to the level of drying to the whole tree (Table 2).

Indigenous coffee field management

Almost all the studied households grow the agroforestry tree species such as *Albizia tanganica, Cordia africana, Erythrina abyssinica*, and *Millettia ferruginea*, which are found to augment coffee yield since many of the trees fix nitrogen and possess large biomass that increases soil fertility. However, pruning coffee shrubs was found practiced by less than 50% of the study households that may increase the transfer of pests and reduce coffee productivity. About 35% of the sample households failed to prune agroforestry tree species which harbored some coffee diseases such as Coffee berry disease.

Most local people practiced regular picking to control some pests such as coffee berry borer. For the commonly identified pest organisms like Choroqa (mealy

Figure 5. The load of coffee berry borer on coffee berries.

Table 2. The relative damage of major insects on coffee recorded per selected kebeles

Woredas	Kebeles	Common Land races of coffee		Improved variety		Major insect pests
		Kurmie	Welisho	Deiga	Serto	(CBB, CLM, CBM, CWSB)
Wonago	Deko	Moderate	High	Severe	Moderate	CLM,CBB,CBM
	Dobota	Moderate	High	Severe	Low-moderate	CLM,CBB,CBM
Kochore	Golocha	low	High	Severe	Low	CLM,CBB,CBM
	Biloya	Moderate	High	Severe	Moderate	CLM,CBB,CBM
	Anchabi	Moderate	Severe	Severe	Moderate	CBB, CLM, CBM
Yirgachefe	Sede	low	High	High	Low	CBB, CWSB
	Resite	Moderate	High	Moderate	Low	CBB
Dilla zuria	Gola	Moderate	High	Severe	Moderate	CBB, CWSB
	Wachema	Moderate	High	Severe	Low	CBB, CBM
	Otilcho	Moderate	Severe	Severe	Moderate	CBB, CBM
Gedeb	G/Galcha	Moderate	High	High	Low	CBM
	W/chelbesa	Moderate	High	High	Low	CBM

*CBB, coffee berry borer; CBM, coffee bloch minor; CLM, coffee leaf minor; CWSB, coffee white stem borer.

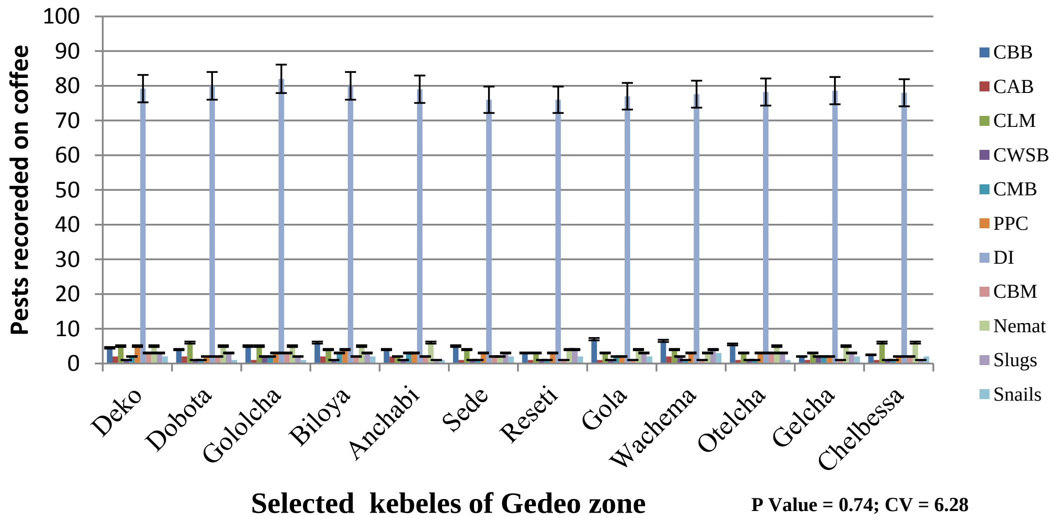

Figure 6. Pest diversity per kebeles of Gedeo zone. CBB, Coffee berry borer, CAB, coffee anthestia bug; CLM, coffee leaf miner; CWSB, coffee white stem borer; CMB, coffee mealy bug; PPC, plant parasitic on coffee; DI, disease incidence; CBM, coffee leaf bloch miner; Nemat, nematode worms in root.

bug), coffee sap sucking green snake (*Hanjame*), Gindi adrik (coffee white stem borer), and other vertebrates like monkeys and baboon, birds (*cia*), rats (*lema'e*) and thief (robbers) were informed as challenges, and were managed through going over on the farm.

DISCUSSION

The diversity of insect pests and the damage level

The current study investigated thirteen arthropod coffee pests in Gedeo enset- coffee based agroforestry system but Chemeda et al (2015) identified 12 insect families of five insect orders from afromontane rainforests in Southwestern Ethiopia where *C. arabica* L. has originated. There was no statistically significant difference in the damage of coffee plant by various pests (P>0.05) among studied coffee landraces and across the study sites though the highest severity level was recorded by coffee berry borer, *H. hampei*, which is the world's worst coffee pest. Nonetheless, Chemeda et al. (2015) reported significance differences in insect pest occurrence between and within forest coffee populations with regard to coffee leaf damaging insects. The following are important classes of pests addressed in the Gedeo Zone.

Major pests

In the present study, coffee anthestia bug was found sucking green coffee berries, flower buds and growing tips. It was reported that after sucking berries, it finally blackens the flowers, flower buds, and causes fall of immature berries, and shortening of internodes. Similarly, coffee bloch leaf minor was found to cause severe defoliation coffee plant. However, Esayas and Chemeda (2007) reported that it never causes considerably yield loss.

Potentially important insect pests

Coffee berry borer was found the leading pest examined in the current study. It was first reported in 1968 by Davidson in Ethiopia and is currently the leading incidence being reported from different parts of the country (Mendesil et al., 2003). Coffee berry borer was seen attacking the green, ripe and dry berries in contrast to the previous investigation in Ethiopia (Million, 2000). Loss due to coffee berry borer inflict up to 60% damage on dry left over coffee berries in Ethiopia. Climate change particularly the raise in temperature in coffee growing areas has aggravated the problem by creating an environment conducive to the rapid growth of the pest Abdu (Abdu and Tewodros, 2013). The current study identified the black scale and coffee cushion scale causing low level of infestation. Regarding coffee scale insects, seven species were recorded in Ethiopia (Million, 2000). Similarly, the current study found that coffee thrips were seen feeding on leaves and green berries which is similar to the previous investigation by Esayas and Chemeda (2007).This may lead to coffee yeild reduction. However, further investigation on the impact on coffee productivity is required.

Minor insect pests

Serpentine leaf miner, coffee leaf skeletenizer, coffee aphids and fruit flies were among the most common insects observed. Serpentine leaf miner was very common affecting young leaf which outbreaks every year after the onset of short rain. The larvae of coffee leaf skeletenizer were feeding on the underside of leaf usually near mid rib eating everything except veins and upper epidermis leaving irregular lace-like patches. The other minor insect pests were coffee aphids, black soft bodied found in cluster on tips of (soft shoots, flower, flower buds and leaf), causing no direct damage but, can cause premature fall of young green berries. Similar results were reported by Esayas and Chemeda (2007).

Indigenous pest management practices

Various traditional management practices were recognized in Gedeo agroforestry system. For instance, coffee leaf miner, *Leucoptera coffeina* is often seen in shaded coffee causing minor impact, but considered as major pest by the growers in the study area. They manage density and canopy of the shade trees and then the number decreases significantly. Coffee berry borer is traditionally controlled by regular picking, take off and burning old and dry cherries while pruning keeps the canopy more open, less humid and unattractive to the pests such as Choroqa (mealy bug), and Gindi adrik (coffee white stem borer).

There are also a lot of techniques that are being used by the coffee growers for the management of pests in Gedeo zone, Southern Ethiopia. For instance, for the prevention of mealy bugs, growers apply adequate nutrition to a coffee plant in the form of fertilizer, mulch or well-rotted manure, and regular inspection and monitoring of on farm before the harvest of coffee berry. Moreover, they grow nitrogen fixing agroforestry trees such as *Erythrina abyssinica* and *Millettia ferruginea* to promote soil fertility and enhance coffee pest and disease protection. Similar practices were reported by Girma (2008). In some cases high density and large canopy shade trees were found to harbor pests such as coffee berry borer. Similar finding was reported by Van Der Vossen (2005). Additionally, failure to manage the old coffee shrubs has resulted in the expansion of epiphytic plants and other parasitic epiphytes to grow on coffee shrub which result in reduced coffee productivity. This requires adequate training and dissemination, particularly the extension workers should promote not only provision of improved crops but also protection of crops from disease and pests. Furthermore, advanced integrated pest management techniques should be operated as coffee is the major crop in the sampled area.

Fortunately, the well-managed coffee farm in Gedeo agroforestry system was less likely damaged by arthropod pests in general. For instance, coffee leaf minor, *L. coffeina* is below threshold level in shaded coffee and so have minor impact. The damage caused by coffee berry borer, *H. hampei* was less than 10% in the study farm sites. The Gedeo indigenous agro forestry system by itself is well managed and does not create conducive environment for pest outbreak, that is, acts as a physical barrier. The exposed coffee trees are evidence for this, since they are more attacked by pests compared to coffee trees found under shades. This could be associated with the presence of diverse natural enemies, which will keep the population at low level as described by Girma (2008). As a result, the agroforestry system is well suited for the diversity of pests and their natural density maintained below economic injury level. This is one of the components of IPM and need to be conserved for its sustainability.

CONCLUSION AND RECOMMENDATIONS

Four different coffee landraces were examined from Gedeo agroforestry system. Similarly, thirteen arthropod pests and five non arthropod vertebrate pest species were found to depend on coffee regardless of the landrace type. To recap, low damage level was examined by insect pests from the present study area regardless of the coffee landrace types. There were relatively insignificant insect pest problems in Gedeo indigenous agroforestry system as compared to coffee diseases that is caused by fungal /bacterial pathogenic agents, which could be associated with the presence of genetically diverse *C. arabica* as well as the existence of diverse natural enemies in complex agroforestry system of Gedeo Zone, that may keep the population of pests at low level. Gedeo indigenous agro forestry system contributes great in hosting diversity insects and natural enemies and have great role in an IPM strategy and need to be further studied for biological control.

The denser the canopy, the higher the probability of coffee infection was resulted. Among the four coffee landraces examined in this study, kurmie was preferred by 75% of the growers due to its better resistance to pests and disease.

Insects contribute much in vectoring pathogenic microbial infections. Other parasitic epiphytic plants (mosses, ferns and lichens), Dodder and *Loranthus* species were also found another challenge and needs cautious removal. The infected plant parts were dumped around the field (farm land) which acts as the inoculum for further infection. Since the growers are not properly coordinated and guided by the professionals, they are not managing their coffee plantations well in almost all sites, and they need to follow the wider spacing and pruning, making less dense canopy, use of resistant varieties and avoiding frequent replacement of seedlings per uprooted wilted trees. Thus, appropriate training should be given to relevant coffee farmers.

The knowledge gap among farmers in coffee management like spacing, removal of infected coffee, shade trees treatment, conserving biocontrol agents, using resistant variety, consulting professionals and implementation, disease prevention, shade and environmental management were among the major problems in the study area.

Future trend in coffee production

There were some limitations in this study, mainly the absence of continuous monitoring for the prevalence of insect pests and their temporal variation. Implementation of IPM should be taken as the first option in the future through coffee tree/canopy tree management, that is, minimizing the shade level, proper spacing, removal of infected and old plants, coffee field rotating, using resistant varieties and looking for improved varieties.

Conflict of Interests

The authors have not declared any conflict of interests.

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The role of indigenous people in the biodiversity conservation in Gamo area of Gamo Gofa zone, Southern Ethiopia

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The Gamo indigenous people and their knowledge on the biodiversity conservation represent one of the oldest traditionally intensified systems in Ethiopia. Indigenous peoples and their socio cultural relationship with biological systems have largely been contributing to sustainable conservation of biodiversity. The main objective of this study is to analyze the role of indigenous peoples and their knowledge on biodiversity conservation. For this research key informant interview were carried out to generate primary data. The collected data was analyzed using descriptive statistics such as percentage. Accordingly, the indigenous biodiversity conservation method dominantly owned by Gamo peoples was home garden/traditional agro forestry practice. These age-old systems are receiving increasing attention owing to their perceived potential to mitigate environmental problems such as loss of biodiversity and high concentration of atmospheric carbon dioxide. Lack of prioritization for indigenous people due to neglect, decay, as well as destruction of socio-cultural values and their knowledge on the biodiversity conservation were the reasons for the degradation of biodiversity. Therefore, this article came up with the evidence of culture, spiritual, social and ethical norms possessed by indigenous peoples have often been determining factors for sustainable use and conservation of biodiversity.

Key words: Indigenous people, indigenous knowledge, Biodiversity conservation, Gamo area.

INTRODUCTION

Ethiopia has known indigenous people and developed indigenous knowledge in a wide range of fields like soil and water conservation, seed selection and preservation, advancement of traditional farm implements, development of appropriate farming systems, and adaptation of effective coping mechanisms withstanding food insecurities through time. It has well appreciated indigenous technologies that have been devised by the community, using their own indigenous knowledge to cope up harsh time and be able to sustain the livelihoods. For instance, farmers around North Ommo commonly use Moringa stenopetala for food; to purify water, as a detergent, and for medicinal purposes (Norbert et al., 2002). In Eastern Hararghe, remnants of the Harla

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Civilization could be observed (near Dire Dawa) where improved soil and water conservation practices are still traceable. Advanced soil and water conservation in Konso is a well-known living example of strategy to cope up with moisture-deficient soils and is still sustaining the livelihoods of the ever-increasing population (Besha, 2003). Farmers in Kindo Koisha woreda (southern Ethiopia) mitigate the problem of declining soil fertility through organic manuring, a succession of specific crops and short fallow at the lowland (Elias, 2002). Farmers in Tikurso catchments (northern Ethiopia) rank the qualities of their land by using slope, soil depth, soil fertility (quality), agro climatic zones and water logging as criteria (Bekele, 1997). Likewise, multilayer indigenous agro forestry land-use system in Gedeo (Southern Ethiopia) has helped farmers to survive difficult times in their history (Kanshie, 2002). The Borana pastoral community practiced regulated water use through local leaders to conserve water for livestock and human use during the dry period (Chemeda et al., 2005). In addition, soil conservation practices of farmers in Maybar, south Wello (Beshah, 2003) and indigenous irrigation system in Amaro Special Woreda, southern Ethiopia; where farmers constructed waterways over gullies using grooved big logs and the diversion structure is constructed of thrash and tree branches (personal communication) are some of the indigenous technologies that can be cited.

The Gamo people are one of the Omotic speaking groups of South-western Ethiopia. They speak a language that closely relates to Gofa, Wolayta and Dauro. The forty societies (Deres) of the Gamo highland live in areas ranging in size from five to fifty square miles (Olmstead, 1975). During the nineteenth century this area was politically autonomous and divided into small territorially discrete political units called Deres, each with its own hereditary king locally called as (Ka.o).

The Gamo indigenous peoples possess their cultural practice which plays a significant role in the conservation and maintenance of biodiversity. According to Desalegn Desissa, a plant ecologist (2007) who has studied the area, the Gamo's "traditional activities depend on a harmonious relationship with the local environment, which frequently contributes to minimizing environmental disruption and thereby maintaining an overall ecological equilibrium." In the highlands, the Gamo have protected at least 272 sacred groves along waterways and on the tops of hills, these being the remnant forests of formerly vast Afromontane woodlands. Within the groves, the people keep their ritual relics and perform sacrifices, healings, harvest rituals and fire ceremonies that symbolize the connection between the past and the future. There are rainmaking and rain stopping ceremonies and thanksgiving rituals, all of which recognize the peoples' dependence upon the earth to provide for their sustenance and livelihoods. Many groves are also bossa (burial grounds). Surrounding these burial forests are balee (grasslands) where people mourn but which also function as buffer areas that are off limits to grazing and cultivation. Besides protecting sacred groves, the Gamo continue to practice organic and terraced cultivation and composting, which has greatly controlled soil erosion and water pollution and allowed them to cultivate 91 present of their total land area. Careful use of manure as fertilizer is a key to soil fertility throughout the region.

According to Desissa (2007), the sacred groves are "believed to be the gray hairs of Gamo elders; they are a paternal symbol, a protector of communities against misfortunes." A study by the Ethiopian Wildlife and Natural History Society found that biodiversity in sacred groves is higher than in non-sacred forests and that the sacred groves are often a refuge for plant species that have been eradicated in other areas. The groves also contain great numbers of endemic species, making the highlands exceptional for East Africa. In each of the sacred groves scattered across the region, an eqaa (ritual leader) is responsible for leading community ceremonies and is also considered the "father" or traditional custodian for the grove. In this system, knowledge is transmitted to younger generations from stewards of the spiritual life, who hold the community responsible for the protection and well-being of the lands and waters. However, the issues of indigenous peoples, their socio-cultural values and knowledge on the biodiversity conservation are not prioritized in the Gamo area. Therefore, the main objective of this study is to analyze the role of indigenous peoples and their knowledge in biodiversity conservation.

MATERIALS AND METHODS

Location

The study was conducted at Gamo areas in three woredas (Chencha, Mirab-Abaya and Arbamich Zuriaworeda) around Arbaminch town, in the Southern Nations, Nationalities and Peoples Regional state. Arbaminch town (6° 02' N, 37° 36' E) is located at 505 km south of Addis Ababa at an altitude of 1350 m a.s.l. The relief setting is mountainous, rugged, hilly and undulating. The region includes some basaltic highlands in the north and to the west of Lakes Abaya and Chamo and some crystalline highlands to southern extremes (Murphy, 1968).

Climate

The long-term weather information at Arba Minch Meteorological station revealed that the rainfall pattern of the study area is a bimodal type with a total rainfall of 830.7 mm per annum. The major peak in April and another small peak in October, extends from April to October with maximum rain in the months of June, July and August. The mean minimum, mean maximum and average temperatures are 14.1, 27.9 and 20.6°C, respectively. Chencha woreda is in cool-semi-humid zone (highland) while Mirab-Abaya and Arbamich zuria woreda areas are in warm semi-humid zones (lowland). The temperature in the areas varies and ranges from 16. 2 to 32°C. The vegetation of the study area is quite diverse and can be divided into *Acacia-Commiphora* woodland (lower portion) and *Combretum-Terminalia* woodland (upper portion). Though natural forests have disappeared in many places due to shifting agriculture, a rich floristic diversity can still be marked in these forests.

People

The Gamo people are one of the Omotic speaking groups of South-western Ethiopia. They speak a language that closely relates to Gofa, Wolayta and Dauro. The forty societies (Deres) of the Gamo highland live in areas ranging in size from five to fifty square miles (Olmstead, 1975). During the nineteenth century this area was politically autonomous and divided into small territorially discrete political units called Deres, each with its own hereditary king locally called as (Ka.o).

Gamo indigenous knowledge

Gamo indigenous knowledge is knowledge of an indigenous community accumulated over generations of living in harmony with their environment. It is a broad concept that covers forms of knowledge, technologies, know-how, skills, practices and beliefs that enable the indigenous community of Gamo to achieve stable livelihoods in their environment. It is traditional cultural knowledge that includes intellectual, ecological, technological, and medical knowledge.

The Gamo indigenous communities had a vast stock of knowledge on prediction and early warning of rainfall, weather forecasting, time-testing coping mechanisms, food production and storage techniques, and an impressive plant-based pharmacopoeia for both human and animal health. For instance, in the field of prediction and early warning of rainfall, the Gamo indigenous community have a large number of climate monitoring indicators that enabled them to tell such things as the right time to start soil and water conservation practice, to start planting in anticipation of the rains or to preserve and store food in anticipation of a dry season as well as help to determine the rainy season (*Baliggo*) and dray season (*Bonne*) in order to plan and design the cultivation and tillage type. These indicators included observation of the movement of sun, moon and star, behavior of animals, birds, reptiles, amphibians, insects, vegetation and trees, celestial bodies, winds and level of temperatures.

Many of the Gamo indigenous knowledge approaches to environmental conservation included such technologies and practices as shifting cultivation, mixed cropping or intercropping, minimum tillage and agro-forestry, home garden as well as transhumance. These technologies and practices were common place and were used with various other methods of land use and management to promote higher yields and at the same time conserving the environment.

The Gamo indigenous people's mind also possesses detailed information about species of plants, animals, and some microorganisms; they also recognize types of minerals, soils, landforms, vegetation and landscapes. In case of soil, black soil (*Karetta Bitta*) which is suitable for growing crops such as sweet potatoes and potatoes. In case of microorganism: they also decide the type of microorganism those are living in soil to decompose organic matter of a soil through using smell of soil and observing the soil color. If the soil have deep dark color and pungent smell, they decide that the soil contain soil microorganism called as Bacteria (*Bitta Modhdhisiza Guutunne*).

Gamo community based organization

Gamo community based organization is traditional mutual assistance organizations developed within community by community on Kebeles level provide a model for closer community services/ community interaction. This organizations named as (*Iddir, Iqube, Dego (Yusho*)). *Iddir*is a voluntary and most widespread association in the Gamo area but its composition, system, approach and size may differ from village to village. But all over Iddirs are communities oriented and mostly religiously and ethnically heterogeneous unless the vicinity is homogenous. They are characterized by high commitment, participation, constructive dialogue and cooperation of members and had been engaged in security, development issues and social issues long and developed at village. Mostly the primary aim of iddirs is at least in their initial stages and now in some cases the provision of mutual support in time of death. Among the functions of iddirs decent burial comes first and foremost to bind all together. Both rich and poor, young and old, healthy and sick die.

The suitability of another common mutual assistance organization, the *Eqqub*, is a rotating saving and credit scheme, where members contribute constant amount of money each period and collect a sum of pooled money when it is their turn. It is an efficient and flexible savings institution benefiting particularly women and lower income households in the community. Furthermore, *Debo*is mutual help associations of labor share arrangement of agricultural work groups in Gamo area which is formed by Gamo people living in the same neighbourhood has leased by the representatives who voted through the agreement of peoples from the member of it. The number of member based on the interest off the participants sometimes the topography of a farm land as limiting factors of the number of the *Debo*.

Source of data and analysis

The study approach includes both secondary and primary data collection method to generate appropriate information for the study. The primary data were obtained through key informant interview. The interviews were focused to collect data on the relationship between indigenous peoples, their knowledge and culture on the biodiversity conservation to answer the research questions: Why the indigenous peoples and their knowledge are critical in biodiversity conservation? How are indigenous peoples, their knowledge, biodiversity and culture related between each other? And also focused to collect data on the their strategies for the conservation and improvement of the resources necessary for survival and dominant biodiversity practice implemented on the community to mitigate climate change and adaptation to answer the research questions: Which biodiversity conservation method that is practiced by Gamo Indigenous peoples could contribute to climate change mitigating and adaptation in the Gamo area? And their coping approach adapted to overcome problems associated with the degradation of biodiversity could be associate with what are the main causes and consequences of biodiversity degradation in the Gamo area? Whereas, secondary data were collected through an examination of the peer-reviewed literature, as published in journal and books for the data of dominant biodiversity practices in the Gamo area.

Sampling and sampling procedure

Three woredas (Chencha, Mirab-Abaya and Arbamich Zuria woreda) were purposively selected from the Gamo Gofa zone based on their accessibility and relevance to the proposed study. After the study woradas where identified, 27 key informants were selected purposively from the three woredas.

Key informants interview

Key informant interviews were carried out with elder people and

Table 1. Summary of key informants during interview.

Name of representative Woredas	Gamo elders from each woredas		Community based organization (Debo(yusho), IdirIquib		Top governmental office of woreda agriculture and rural development bureau		Total
	Male	Female	Male	Female	Male	Female	
ArbaminchZuriaWoreda	3	2	2	1	1	----	9
Mirababayaworeda	3	2	3	----	1	----	9
Chenchawored	3	2	2	1	1	----	9
Total	9	6	7	2	3	---	27

Source: Survey data, 2012.

community based organization representatives, top governmental office of woreda agriculture and rural development bureaus, who know the history of the areas very well. The elders from each woredas have been above 50 years old, acceptable by community for different social and cultural affairs. By the above selection criteria the sample size were 5 per woreda from elders, three per woreda for community based organization and one per woreda from top governmental office. Therefore, the total sample sizes were twenty-seven (Table 1).

Data analysis

The quantitative data was analyzed using both descriptive and inferential statistical tools like percentages whereas qualitative data where analyzed by cross checking with different data sources in the study area.

RESULTS AND DISSCUSION

Values of Gamo indigenous knowledge in the biodiversity conservation

Gamo indigenous knowledge is essence of the social capital of Gamo peoples and plays a significant role in conservation of biodiversity. Local culture, spiritual, social and ethical norms possessed by these peoples has often been determining factors for sustainable use and conservation of biodiversity. According to the 45% of key informant interview responds, indigenous knowledge owned by the Gamo people to conserve biodiversity are shifting cultivation, sacred groves, local method of soil and water conservation practice (physical and biological structure) were as according to 55% of key informant interview responds, home garden/traditional agro forestry practice, locally known as *Daniiogade* in the Gamo language are dominantly used to biodiversity conservations.

Some researchers are carried out on home-gardens in detail in certain localities of the Gamo area by Belachew et al. (2003), Southern Ethiopia (Tesfaye, 2005) in Ochollo, Channo and Lantee kebeles in low land part of Gamo area are stated as traditional home-gardening is a sustainable agricultural practice; it is environmentally friend and also allows the harvesting of diverse products to the satisfaction of farming families as well as urban dwellers. This farming system that is composed of diverse and complex vegetation arrangements deserves unique nomenclature as it shares more with natural forests than it does with man-induced agro-ecosystems. According to the Gamo community based organization representative responds, the cultivated garden plants are composed of both food and non-food species.

According to woreda agriculture and rural development bureau representative responds the most Gamo women encouraged the neighbors, husbands and youths to conserve home gardens by planting diverse plant species and by taking proper care of the gardens. As they said, women's play a silent but active role in home garden conservation and management of plant genetic resources and seed selection. Talemos (2007) reported the same results. During key informant interview with the elder women's, it was notice that women were interested because they thought that home gardens could help them to earn and save money. However, many were also interested in preserving the environment and reducing biotic pressure on forests.

Role of home garden in the climate change mitigation and adaptation

Based on the 65% of key informant interview responds, pollution (water, soil, air and noise), stream cuts, erosion, flood, rugged topography and quarry were identified as the potential hazards/constraints of biotic resources in the Gamo area but 35% of KI respondents, erosion, flood and rugged topography and quarry were identified as the potential hazards/constraints of biotic resources in the Gamo area. As they explained, water and soil pollutions emanated from improper disposal of urban and poorly regulated wastes from industries, unwise uses of chemical fertilizers and locally produced beer (locally Areke, and Tella). In Gamo society, almost all of the generated solid wastes are indiscriminately dumped into drainage channels, streams, open surfaces, culverts, and residential compounds and even on the road including highway passing through the town. Open air combustion of wastes and emission of gases from factories in the area without effective treatment design can be the cause for air pollution. However, as they said that the contribution of home-gardens of the study area in sustaining the environment is promising. These Home garden, developed and nurtured by Gamo local farmers through generations of innovation and experiment, are often cited as the epitome of sustainability, yet have been long neglected by the developmental activities. Today, however, these age-old systems are receiving increasing attention owing to their perceived potential to mitigate environmental problems such as loss of biodiversity and high concentration of atmospheric carbon dioxide. According to Ajibade and Shokemi (2003) it is widely recognized that agro-forests play an important role in the global carbon cycle by sequestering and storing carbon(C).

During the interview, woreda agriculture and rural development bureaus pointed out that this homo garden plants help remove pollutants from the air in three ways: absorption by the leaves or the soil surface; deposition of particulates and aerosols on leaf surfaces; and fallout of particulates on the leeward (downwind) side of the vegetation because of the slowing of air movement. In line with this, home-gardens of the study area offer relevant service in mitigating the currently aggravating trend of climate change and in rehabilitating soil degradation. Soil erosion is minimized because of high vegetation cover that prevented the exposure of bare ground to heavy rainfall, improve the soil structure and increase the level of organic nutrient through the literal fall and releasing nutrient contain fluid through their roots. This help to increase the infiltration rate of the soil and also help to keep healthy soil. The healthy soils are a medium for sustainable growth of diversity plant and clean the environment through the process of organic matter decomposition. In addition, shades of trees, shrubs and other vegetation help to control temperature extremes by modifying solar radiation. Moreover, trees in the homesteads are also used to intercept dust. Since there is almost no use of pesticides in gardening, their produce is ‘clean’ contributing to environmental protection as well as public health. Therefore, this home garden practice of the study area have dual service of reducing the emission of GHG (Green House Gas) from anthropogenic sources, and enhancing carbon ‘‘sink’’. As they reported that ‘’home garden also play a significant role in adaptation to the local climate change through practices of the planting early maturing crops, adoption of hardy varieties of crops and selective keeping of livestock in home garden’’.

Causes and consequences of biodiversity loss in the Gamo area

According to (100%) of Gamo indigenous elders respondents, the main causes for the loss of Gamo biodiversity are: neglecting of local-biodiversity relationship through belittling of local knowledge, beliefs and practices has led to a disconnection of local peoples from their local nature (biodiversity). As they explained that when the links of local people with nature have been severed, it becomes difficult for local people to wake up to the call to take up their responsibilities to care for and work with nature for their own good (let alone for the good of nature and others). This eventually results in the loss of culture and biodiversity. This lead the development programs implemented in such an area of Gamo are hardly appropriate and will very likely be unsuccessful. Therefore, Gamo local communities have often been led to believe that their own way of life, depending on local biodiversity must be shunned in favor of alternative lifestyles. These alternatives, however, usually alter traditional patterns of interaction with the environment beginning with mismanagement and eventual destruction of local biodiversity and cultural practices.

According to (100%) of Gamo community based organization representatives respondents, the main causes for the biodiversity loss are policy failure: The policy and legislative frameworks do not articulate strategies specific to the conservation and sustainable use of biodiversity for Gamo indigenous people. As they said, migration from rural areas to towns and resettlement of people from drought-stricken regions to fertile areas has also resulted in the deterioration of traditional practices. As they reported, lack of prioritization for indigenous people due to neglect, decay, as well as destruction of socio-cultural values and their knowledge on the biodiversity conservation were the other reasons for the loss of biodiversity.

Furthermore, woreda’s agriculture and rural development bureau respondent pointed out that the misunderstanding of the principle of conservation by those conservationists and developers who have considered conservation strictly as the act of keeping biodiversity from change or loss, by protecting and preserving it or preventing, disallowing and denying the use of biodiversity by people in order to “save biodiversity”. As they said, these forget that the natural biological systems as well as cultures are dynamic and not fixed. If these systems are dynamic then we cannot keep them from changing. They must rather work within these systems and help them attain their balances through change. On other hand, if the principle of conservation has been understood, then actions on the ground have indicated that the principle has been misapplied. This misapplication whatever in Gamo area on the ground results as regards development and biodiversity conservation programs have not been satisfactory.

Almost all interviewees quite agreed the impact of biodiversity loss lead to the Gamo indigenous peoples particularly youth to long-term-long distance internal migration on the women left behind in local areas. This indicates that the livelihood of women who are left behind as the male household head migrates out is highly affected by the labor gap and the social, cultural and institutional barriers, which constrain women's effort to improve and diversify their livelihood and come out of poverty and food insecurity. Women heads reported, labor gap at household level has forced most women to reduce the acreage of land they cultivate or leave some of their plots fallow. As a result women heads reported a decline in their agricultural production and high reliance on purchased food for survival. Were women effectively take over home garden conservation when household heads migrate out, in the study area the labor demanding tasks like land preparation and Enset transplanting are practically impossible for women to stay in the home garden conservation. It is also learned that reliance on hired labor has a lot of negative effect on the conservation of home garden lead to decline in the productivity of diversity.

Especially the Gamo elders in Gamo highland part (Chencha woreda from Bilala and Shaye kebele) reported that they are facing much greater problems in recent years in drought due to erratic rain fall distribution lead to the scarcity of water. Dry-season grazing and watering areas have dried up, the water table in the shallow wells has fallen, and there is little or no water for the livestock as well as humans' nascent efforts to practice small-scale irrigation. As they said that, this problem is not common before ten years ago and happen suddenly due to the loss of our guard crop Enset is key position in the country's home-gardens as a dominant species is mentioned by Zemede (2002) which play a significant role as source of water and food for livestock and human. As a result, they said that they have to move their livestock further away to non-traditional grazing areas, that is, into the territory of their enemies, although they were fully aware that this could lead to more conflict.

Conclusions

Indigenous peoples and their socio-cultural relationship with biological systems have largely been contributing to sustainable conservation of biodiversity. Field-based studies or interview were identified that the indigenous knowledge dominantly practiced to conserve biodiversity were the practice of home-garden in small scope traditional agro ecosystem having diverse plant species was carried out in Gamo area of South Ethiopia. Gamo indigenous farmers have well founded ingenious knowledge to conserve home garden and manage each components of the system. One major endeavor is the maintenance of diverse taxa of plant species in the home-gardens that are grown for food and others. This practice has a significant role on the biodiversity conservation and climate change mitigation and adaptation of Gamo peoples. The major causes for biodiversity degradation are neglecting of local-biodiversity relationship through belittling of local knowledge, beliefs and practices and policy failure. Based on this, it is possible to conclude that indigenous people and their knowledge are playing a significant role in the protection of environments well as biodiversity.

Conflict of Interests

The authors have not declared any conflict of interests.

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Spatial and temporal dynamics of foraging habitat availability for reddish egrets in the Laguna Madre, Texas

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The reddish egret (*Egretta rufescens*) is the rarest heron in North America and much remains to be learned about in the ecology of the species. The reddish egret is a foraging habitat specialist and relies on shallow coastal ecosystems. There is a paucity of information on foraging habitat requirements and the availability of foraging habitat throughout the annual cycle. Characteristics of foraging habitat at locations within the Laguna Madre, Texas where reddish egrets were observed foraging were measured. These characteristics were used to conduct a geospatial analysis that estimated the spatial and temporal distributions of foraging habitat in the Laguna Madre across 120 weeks from 2012 to 2014. Reddish egrets (*n* = 372) foraged in an average water depth of 10.1 ± 0.68 cm and in areas with average seagrass cover of 12.3 ± 2.74%. Approximately, 75 000 ha of foraging habitat were delineated to be available in the Laguna Madre across the study period; of this, 4 003 ha were available ≥ 50% of the time. The amount of available foraging habitat was relatively high during the spring and summer, and decreased by ~50% during winter. This model-based approach can be used throughout the species' range to examine foraging habitat availability which is a current conservation need according to the Reddish Egret Conservation Action Plan.

Key words: *Egretta rufescens*, foraging habitat, Laguna Madre, reddish egret, Texas.

INTRODUCTION

The reddish egret (*Egretta rufescens*) is the rarest Ardeidae in North America and is highly restricted geographically (International Union for Conservation of Nature, 2012). It is a coastal wetland specialist found along the Gulf of Mexico, the Caribbean and Bahamas, the Atlantic Coast of Florida, and the Pacific Coast of

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Figure 1. Location of the Laguna Madre, Texas where reddish egret foraging habitat was assessed during 2012-2014.

Mexico (Lowther and Paul, 2002). The reddish egret was nearly extirpated early in the 20th century due to plume hunting, and today there is an estimated 2000 breeding pairs in the United States with nearly half occurring in Texas (Lowther and Paul, 2002; Green, 2006). Because of its narrow habitat requirements and limited distribution, the reddish egret was listed as a species of concern by the U.S. Fish and Wildlife Service. It is also listed as near threatened on the International Union for Conservation of Nature Red List (2012).

Foraging habitat of the reddish egret typically consists of shallow coastal flats and lagoons where it actively forages for small fish such as sheepshead minnow (*Cyprinodon variegatus*), longnose killifish (*Fundulus similis*) and pinfish (*Lagodon rhomboids*) (Lowther and Paul, 2002). Because the reddish egret is restricted to coastal areas, it is sensitive to disturbances and alterations within these habitats. The rapidly growing human population along the Texas Coast has had major impacts on coastal habitats (Moulton et al., 1997). The Gulf Intracoastal Waterway is frequently dredged and new sites are needed for dredge disposal. Placement of dredge material can alter tidal flat habitats by covering seagrass meadows that provide habitat for fish, impacting water quality, and changing the hydrology of foraging areas for waterbirds (Farmer, 1991). Therefore, an understanding of the spatial and temporal dynamics of foraging habitat will enable managers to reduce negative impacts to these areas and support foraging requirements for this unique species. In fact, the recently developed Reddish Egret Recovery Plan (Wilson et al., 2014) specifically states the identification of key foraging areas as one of three primary goals. Consequently, the goal of this study was to develop a spatial model that delineates the temporal distribution of foraging habitat for the reddish egret in the Laguna Madre of Texas and to test the performance of the model with an independent sample of locations of foraging reddish egrets marked with GPS equipped satellite transmitters.

METHODOLOGY

Study area description

The Laguna Madre is located along the lower Texas Coast (Figure 1) and supports the largest concentration of reddish egrets in North

America (Green, 2006). It is a large, hypersaline lagoon stretching ~185 km in length with an average width of 7 km, and relatively shallow water depths, averaging 1 m deep (Tunnell, 2002). Tides in the Laguna Madre are mainly wind-driven and can cause water levels to fluctuate by 0.6 to 0.9 m (Tunnel, 2002). Seagrass meadows and wind tidal flats are the primary habitat types found in the Laguna Madre. Shoalgrass (*Halodule wrightii*) and manateegrass (*Cymodocea syringodium*) are the dominant species in the upper and lower Laguna, respectively (Quammen and Onuf, 1993). Islands are abundant and widespread throughout the Laguna Madre, most of which were formed by placement of dredge material during construction and routine maintenance dredging of the Intracoastal Waterway (Tunnell, 2002). Some of these islands have become occupied by colonial nesting waterbirds, including the reddish egret.

Foraging observations

Habitat of foraging reddish egrets observed throughout the annual cycle (about every 2 weeks) from March 2008 to April 2010 were sampled. The Laguna Madre was divided into six zones for sampling purposes, and each survey day we systematically searched a zone by boat for foraging reddish egrets. Foraging individuals were observed for 20 min or until foraging ceased. Observations were made from >150 m to reduce any influence on foraging individuals. Color morph and age (hatch-year or after hatch-year) were recorded for each individual observed. Plumage characteristics and bill color were used to identify juvenile birds (Cézilly and Boy, 1988; Farmer, 1991). Dark morph hatch-year individuals are mostly gray with little if any distinction in color between the head and neck, and the rest of the body. The plumage of white morph hatch-year birds is completely white like the adults. However, hatch-year birds of both color morphs lack the plumes and bicolored bill of adults (Lowther and Paul, 2002). Birds were identified as either foraging in groups or solitarily (referred to as foraging class). A group was ≥ 2 egrets foraging with < 30 m of spacing between individuals during most of the observation period (Bates and Ballard, 2014). Coordinates at the center of the foraging site for each sampled individual were determined with a GPS unit, and a transect was established along the path of the foraging egret. A 1-m quadrat was used to measure percent seagrass coverage and seagrass species composition at ≥ 5 points at 25-m intervals along the transect. Water depth was measured at each quadrat sampling point. We averaged across sampling points on each transect to determine average water depth and percent seagrass cover for each bird. t-tests were used to examine differences in water depth and percent seagrass cover between ages, color morphs, and foraging class (solitary or group) as foraging success or habitat use by reddish egrets have been shown to differ between ages (Bates and Ballard, 2014), color morphs (Green 2005) and foraging classes (Bates and Ballard 2014). Habitat data collected during observations was used to develop this study model and examine foraging habitat availability for subsequent time periods.

Model building

Optimal water depth for foraging reddish egrets was determined to be 1 to 20 cm based on ~ 90% of the sample foraging within this range. A raster dataset of bathymetry (60 x 60 m grid size) for the Laguna Madre (United States Army Corp of Engineers, unpublished data), Digital Elevation Model (3 x 3 m grid size; United States Geological Survey, 2009), and tide readings from four tide gauges in the Laguna Madre (National Oceanic and Atmospheric Administration Tides and Currents, 2014) were used in ArcGIS 10.1 ModelBuilder (Environmental Systems Research Institute, 2011) to ModelBuilder (Environmental Systems Research Institute, 2011) to determine weekly changes in water depth and extent of available foraging habitat during January 2012 to April 2014. The bathymetry dataset did not extend completely into the tidal flats so the Digital Elevation Map, created from Lidar Imagery (10 x 10 m grid size) was merged with the bathymetry dataset by creating a 300-m buffer on the landward border of the bathymetry polygon and a 300-m buffer on the border of the Digital Elevation dataset where it met the Laguna Madre. Next, 10 000 random points were generated in the bathymetry buffer polygon and 10 000 random points in the Digital Elevation dataset buffer polygon. The values of the bathymetry layer and the Digital Elevation layer to the random points were extracted, then the two random point datasets were merged into one layer and an Inverse Distance Weighted analysis was performed to interpolate the values between the two layers to provide a fluid merging process of the two raster datasets. The three datasets (bathymetry, digital elevation and the created dataset interpolated from random points) were mosaicked into one raster layer at a 3 x 3 m resolution. The combined dataset resulted in a gradual merging of values between the bathymetry data and the Digital Elevation Map data over the areas that were not covered by either dataset. Observations of foraging reddish egrets in the Laguna Madre indicated that forging was most intense from sunrise to 10:30 (Bates, 2011). Therefore, 08:30 (median time) was chosen as a reference time to interpolate the tide throughout the Laguna Madre. One weekday (Wednesday) was randomly chosen and tide gauge readings from that day at 08:30 were used each week for the 120 weeks from 4 January 2012 to 16 April 2014 to estimate weekly water depth throughout the Laguna Madre. Readings from the tide stations in the Laguna Madre were used along with the inverse distance weighted tool in ArcGIS 10.1 to interpolate the tide. The interpolated tide was then combined with the merged bathymetry–DEM dataset using the raster calculator tool to obtain water depth throughout the Laguna Madre. The resulting data layer was reclassified giving water depth between 1 and 20 cm, a value of one, and all other depths a value of zero.

The Coastal Bend Texas Benthic Habitat dataset for the Laguna Madre was also used to help delineate foraging habitat based on benthic characteristics (National Oceanic and Atmospheric Administration Ocean Service, Coastal Services Center, 2008). Benthic habitat types classified as suitable reddish egret foraging habitat were based on our results of seagrass coverage from sampled foraging locations, as well as habitat descriptions by Farmer (1991) and Lowther and Paul (2002). Suitable habitat types were given a value of one and included unconsolidated bottom, patchy seagrass, bivalve reef, land and unknown benthic. All other habitat types including continuous seagrass and emergent marsh were coded as zero, indicating that they were unsuitable foraging habitat. The recoded benthic habitat dataset was then multiplied by the reclassified water depth layer to create new layers containing values of zero (unavailable) and one (available) for each week across the 120-week period. The new layers were then converted to polygons to allow calculation of the area of suitable foraging habitat during each week.

Model assessment

To assess the accuracy of this study model, GPS locations of 8 adult reddish egrets marked with satellite transmitters during January 2012 – April 2014 were used. Transmitters were programmed to record locations at 08:00 and 09:00 each morning and 04:00 and 05:00 each evening, which are peak foraging hours (Bates, 2011). We used locations from every day at each of the 4 times (n = 6 385) to assess the model's ability to delineate foraging habitat availability across the 120 weeks. The authors then used locations from only Wednesdays at 08:00 and 09:00 (n = 770) to

Table 1. Mean and 95% confident intervals for water depths (cm) and percent seagrass cover at foraging sites used by 372 reddish egrets foraging in the Laguna Madre of Texas during March 2008 to April 2010 separated by age, color morph and foraging class.

	No.	Water depth	Seagrass cover (%)
Age			
After hatch-year	314	11.0 (10.3-11.7)	12.3 (9.4-15.1)
Hatch-year	58	10.4 (8.3-12.4)	12.0 (3.9-20.1)
Morph			
Dark	191	11.7 (10.7-12.7)	14.9 (10.5-19.3)
White	181	10.2 (9.4-11.1)	10.2 (6.7-13.2)
Foraging class			
Group	161 (21 groups)	11.6 (9.3-13.9)	9.0 (1.7-16.2)
Individual	211	10.9 (10.1-11.6)	12.7 (9.7-15.6)

correspond with each day and assess performance of the model at a finer temporal scale. They considered locations ≤ 50 m from available habitat as 'in' available habitat to account for GPS accuracy (±18 m) and inherent, unknown error in extrapolation of bathymetry and tide data. ArcGIS 10.1 was used to measure the distance from foraging locations to available foraging habitat for each week.

RESULTS

Foraging habitat of 372 reddish egrets that were observed foraging throughout the Laguna Madre were sampled; 211 were observed foraging solitarily, and 161 were observed foraging in groups (n = 21). Average water depth used by foraging reddish egrets was 10.1 ± 0.68 cm with no differences (P > 0.05) between ages, color morphs or foraging classes (Table 1). Approximately, 91% of reddish egrets foraged in water depths of 1 to 20 cm. Average seagrass coverage along transects was 12.3% (± 2.74), and 67% of egrets foraged in ≤ 10% seagrass coverage. There were no differences (P > 0.05) in percent seagrass coverage between ages, color morphs or foraging classes (Table 1).

The Laguna Madre encompasses 215 223 ha of which 123 395 ha were considered potential foraging habitat based solely on benthic habitat characterization (prior to adding water depth to the model). Once water depth was added to the model, available foraging habitat was reduced considerably and varied throughout the annual cycle with a total of 74 985 ha of foraging habitat available at some point during the 120-week period. In 2012, the amount of foraging habitat was relatively low and highly variable from January to mid-March; availability became much higher and remained relatively stable from mid-March through late September, then was again relatively low, but highly variable from October to December (Figure 2a). The lowest amount of available foraging habitat occurred in March (8 608 ha) and peaked at 27 247 ha in late September. In 2013, the overall pattern was similar with relatively large amounts of foraging habitat during April–October, and lower amounts with greater variability during winter (Figure 2b). Foraging habitat peaked at 27 534 ha in July and reduced to 7 099 ha in February. On average, available foraging habitat throughout winter was about 50% of that available during summer.

The availability of a given foraging area fluctuates; the longest duration specific areas available was 82 weeks (2.52 ha). Only 4 003 ha were available ≥ 50% of the time as compared to 51 208 ha available ≥ 10% of the time. Areas containing the greatest amount of foraging habitat in the upper Laguna Madre (Figure 3a and b) were located east of the mouth of Baffin Bay and south to Nine Mile Hole. Large areas of foraging habitat in the lower Laguna Madre were located on the east side, south of the Mansfield Cut, north and south of the Arroyo Colorado on the east side, and south of the Brownsville Ship Channel in South Bay (Figure 3b and c).

It was found that 90% of the GPS locations of foraging reddish egrets fell within our modeled available foraging habitat during the cumulative 120 week period, providing compelling evidence that our model performed well in delineating cumulative foraging habitat across the annual cycle. Less agreement (51%) was found between GPS locations of foraging reddish egrets as compared to corresponding estimates of foraging habitat during each week of the 120 week period. Locations falling outside the estimated foraging habitat deviated with an average of 407 m (median = 180 m) from the foraging habitat boundary and generally were shoreward. About 9% of locations were greater than 500 m from available habitat and in general were on the western part of the Laguna Madre towards the mainland and west of the land-cut. These areas had a much more patchy distribution of

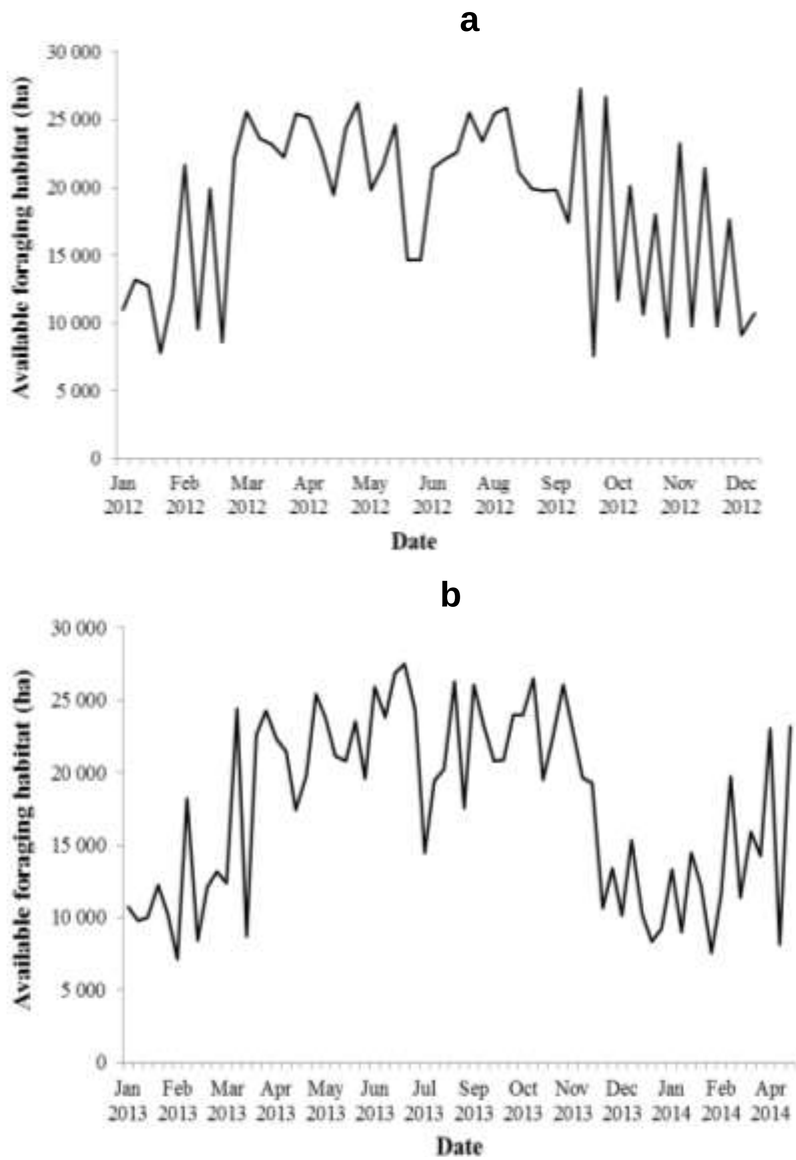

Figure 2. Distribution of available foraging habitat for reddish egrets in the Laguna Madre, Texas in 2012 (a) and 2013-2014 (b).

foraging habitat relative to other areas.

DISCUSSION

This study's foraging habitat model appeared to perform well in estimating the distribution of foraging habitat for reddish egrets in the Laguna Madre, as there was 90% overall agreement with an independent dataset of 6 385 foraging locations from individuals marked with satellite transmitters. The weekly locations (n = 770) were less accurate, with half occurring within available habitat; yet the average distance the locations were from available habitat was relatively small. Potential causes of the reduction in agreement between GPS locations of foraging reddish egrets and the modeled foraging habitat include birds not actually foraging during the time the location was recorded (e.g., flying between foraging locations), inherent error in geospatial datasets and wind-driven water level changes in shallow flats not being accurately recorded by tide gauge stations. However, the influences of these potential sources of variability on modeled foraging habitat that became apparent at finer time scales appear to be less evident when modeled over longer time periods. This model showed that the availability of foraging habitat in the Laguna Madre varied both temporally and spatially. Spatial and temporal fluctuations of foraging habitat in wetland ecosystems is

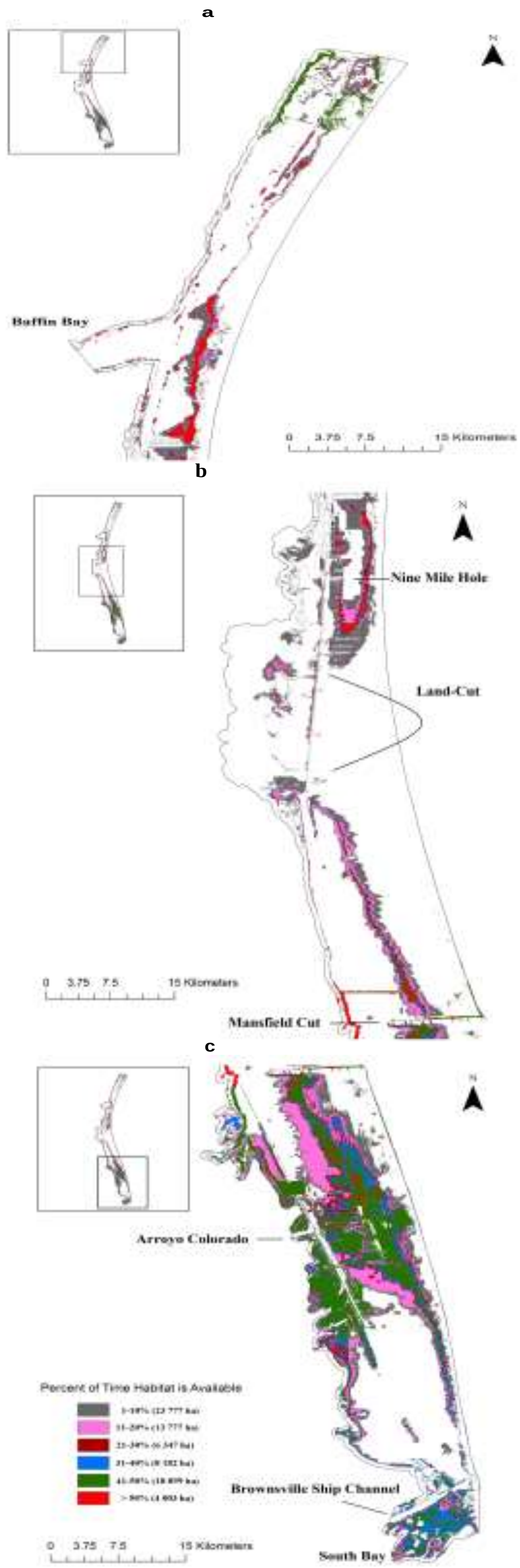

Figure 3. Available foraging habitat for reddish egrets during 120 weeks in 2012–2014 in the upper (a), central (b) and lower (c) Laguna Madre, Texas.

not uncommon; Arengo and Baldassarre (2002) found that size, quality and duration of available foraging habitat for American flamingos (*Phoenicopterus ruber ruber*) varied considerably within and among foraging sites in Yucatán, Mexico. Spatial and temporal variability of wading bird foraging habitat is common due to tidal cycles and variable precipitation (Kahl, 1964; Kushlan 1981; Gonzalez, 1997). Tides in the Laguna Madre are primarily wind driven (Tunnell, 2002); thus, any change in wind speed and direction can cause fluctuations in foraging habitat. The amount of available foraging habitat for reddish egrets was much greater during spring and summer, and large peaks of available habitat occurred within this time period. This period coincides with the breeding season, when energy requirements are high relative to other periods of the annual cycle (Lowther and Paul, 2002).

The amount and location of foraging habitat during the breeding season are important factors to consider when managing this species. The location and size of breeding colonies are often directly related to the availability of nearby foraging habitat (Gibbs et al., 1987; Gibbs, 1997). Green Island in the lower Laguna Madre typically contains the largest abundance of breeding reddish egrets, as well as all other herons and egrets, along the Texas Coast (Texas Colonial Waterbird Society, unpublished data). This island is located proximal to large areas of foraging habitat identified by our model and that are known to be used by reddish egrets nesting on Green Island (Farmer, 1991). Protection of this foraging habitat is likely an important factor in the maintenance of the colony. Likewise, spatially linking foraging habitat to other colonies throughout the Laguna Madre could be beneficial in understanding resources that are critical for sustaining breeding colonies and help reduce adverse impacts from anthropogenic influences (e.g., dredge disposal). More information is needed to examine how reddish egrets utilize foraging habitat in relation to breeding colonies and the distances reddish egrets can travel to foraging sites without reproduction being affected.

The timing of reproduction results in both post-breeding adults and young of the year having large amounts of stable foraging habitat during early fall. Bates and Ballard (2014) found groups of foraging adult and juvenile reddish egrets just after the breeding season from August to October. Farmer (1991) observed a similar pattern of group foraging by hatch-year reddish egrets in fall. Hatch-year reddish egrets are often less efficient foragers and may not be as skilled at identifying quality foraging areas (Bates and Ballard, 2014). The abundance and spatial stability of foraging habitat in fall probably results in hatch-year egrets spending less time and energy searching for quality foraging sites than if there was high temporal variation in availability, and allows them to spend more time foraging to meet their energy demands.

The decline in availability of foraging habitat from December to March corresponds with the time when reddish egrets depart the Laguna Madre during winter and arrive during spring (Farmer, 1991). There is a partial migration of reddish egrets in late autumn, but how far south they migrate is unclear (Paul, 1991). Limited banding data suggest reddish egrets migrate into Mexico and even El Salvador and Guatemala in search of foraging habitat (Paul, 1991). Recently, adult reddish egrets equipped with satellite transmitters were shown to migrate into Mexico during the end of November and beginning of December, returning to the Laguna Madre in March-April (Ballard, unpublished data). Partial migration often occurs when resources become limited and are unable to support the entire population (Ketterson and Nolan, 1976; Lundberg, 1988). The timing of departure from the Laguna Madre during early November by migrant reddish egrets coincides with the decrease in available foraging habitat, indicating that the amount of winter foraging habitat in the Laguna Madre may not be sufficient to maintain the large concentration of reddish egrets in this system.

An initial consideration when prioritizing foraging area for protection should be the temporal extent of its availability. Our habitat model indicated that no foraging habitat pixels (from the final raster image) were available for the entire two-year period and only a small fraction was available more than half of the time. The highly dynamic nature of foraging habitat availability in the Laguna Madre is primarily the result of wind-driven tides (Tunnel, 2002). Because of this high degree of spatial variation in where foraging habitat is located at any time during the annual cycle, it would be required to consider large areas of foraging habitat when devising conservation plans to ensure that enough is available at any given time to sustain the reddish egret population.

Foraging habitat assessment at both smaller spatial and temporal scales within the Laguna Madre may be beneficial in understanding how these habitat dynamics influence reddish egrets. For example, foraging habitat availability during the nestling period influences the provisioning rate by adults, thereby indirectly impacting fledging success. This was the case in the Florida Everglades where nest success of great egrets and white ibises (*Eudocimus albus*) is lower in years with below average prey availability as compared to years with high prey availability (Herring et al., 2010). Prey availability was not examined in this study; however, sheepshead minnow has been identified as a major prey item of reddish egrets breeding in Texas (Holderby et al., 2014) and the habitat of sheepshead minnow largely coincides with the foraging habitat of reddish egrets, that is, shallow water with minimal vegetation. Therefore, foraging habitat availability is likely related to prey availability.

The authors were able to delineate foraging habitat over a large spatiotemporal scale and to identify important foraging areas for protection and conservation, which is a current goal of the Reddish Egret Conservation

Action Plan (Wilson et al., 2014). This model may also be used in future analyses to examine shifts in foraging habitat and the potential impact of sea level rise on foraging habitat availability. Further, it can be used quite effectively to plan dredging operations in the Laguna Madre, by identifying areas where deposition of dredge material will have minimal impacts on foraging habitat for reddish egrets and other waterbirds.

Conflict of interest

The authors have not declared any conflict of interest.

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Population size, habitat association and dietary composition of Boutourlini's blue monkeys (*Cercopithecus mitis boutourlinii*) in Komto Protected Forest, Western Ethiopia

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A study on the population size, habitat association and dietary composition of Boutourlini's blue monkeys (*Cercopithecus mitis boutourlinii*) was carried out from January, 2015 to September, 2016 in Komto Protected Forest. Data was collected for a total of 58 days encompassing both the wet and dry seasons. Scan sampling method was used to collect data on the diet and foraging behaviour of Boutourlini's blue monkeys. Population size was determined by total counting method. A total of two groups (natural and riverine forest) and 29 individuals of Boutourlini's blue monkeys were recorded in the study area. Natural forest group was selected to study about the diet and foraging behaviour of Boutourlini's blue monkeys. The overall dietary composition of Boutourlini's blue monkeys was dominated by young leaves which accounted for 27.40% of the total diet. In addition, they fed on mature leaves (20.3%), fruits (15.38%), flowers (11.24%), shoots (8.99%), bark (6.91%), seeds (4.93%) and animal matter (3.37%). They consumed a total of 21 plant species belonging to 18 families. *Syzygium guineense* was the most consumed plant species and constituted 16.68% of Boutourlini's blue monkey diet followed by *Ficus sur* (13.13%) and *Prunus africana* (12.01%). The most often utilized foraging method was capturing and manipulating food using both hands. This accounted for 47.97% of total foraging observations followed by grabbing (31.46%) and pulling (11.93%). Boutourlini's blue monkeys were restricted to natural and riverine forest habitats in Komto Protected Forest. Preference of such taper ecological niche resulted from selective deforestation for timber and charcoal production, trampling of habitats by livestock and agricultural land expansion. To ensure future conservation of Boutourlini's blue monkeys, habitat rehabilitation, enforcement of laws against deforestation for timber and charcoal production, and other appropriate management and conservation strategies should be designed.

Key words: Boutourlini's blue monkeys, diet, foraging behavior, habitat association, Komto Protected Forest.

INTRODUCTION

Blue monkeys (*Cercopithecus mitis*) are forest dwelling guenons belonging to the Old World monkeys (Kingdon, 1971; Estes, 1992). There are 17 subspecies of blue monkeys spreading in different habitat types and forests of south, east and Central Africa (Wolfheim, 1982). As a species, the conservation status of Blue monkeys is "least concern" with a decreasing population trend (Kingdon et al., 2008). Blue monkeys are mostly adapted to live in the forests and forage at 20 m above the ground (Tashiro, 2006). However, they intermittently move in open habitats and feed on the ground (Stuart, 1997). They are adapted in varieties of habitats such as rain forests, coastal mangrove forests, forest patches in savannah and evergreen semi-deciduous forests (Kingdon, 1971; Estes, 1992). The diets of blue monkeys are mostly flexible (Kingdon, 1971; Chapman et al., 2002; Twinomugisha et al., 2006). The flexibility of diet is associated with their large hindgut specialization to various types of food (Twinomugisha et al., 2006). Fruits were the most frequently used plant components though high amounts of leaves and invertebrates were consumed periodically (Cords, 2002). As an omnivore, blue monkeys mostly feed on fruits, leaves, invertebrates, flowers, seeds, bark and shoots (Estes, 1992).

Blue monkeys are frugivoure primates which are sensitive to the removal of forest as it reduces the availability of food (Cordeiro et al., 2004). Habitat loss due to commercial timber, agriculture and others means of human resource gathering threatens forest specialist primates (Chapman et al., 2006). Remnant forest patches are surrounded by encroachments, overgrazing and agricultural lands. This has caused a number of changes such as reduction of mammal populations, altered diets and foraging behaviours (Mbora and Meikle, 2004). Plant species composition and diversity is low in fragmented and disturbed forests. This in turn affects the availability of food for the species (Wong and Sicotte, 2006). Food supply is an important determinant factor that limits population abundance (Rode et al., 2006; Rovero and Struhsaker, 2007). Loss of food may increase competition between species. It is also the cause for aggressive interactions among animals thereby increasing stress and reduction of reproduction. Consequently, such habitat loss and fragmented habitats leads to local extinction of species (Mbora and McPeek, 2009). Most primates are forest specialists and thus vulnerable to habitat fragmentation (Chapman et al., 2007). As revealed by IUCN (2010), nearly half of the species are threatened with extinction due to habitat destruction and hunting. Most primate species and subspecies are threatened due to habitat loss and degradation in tropical regions (Cowlishaw, 1999; Chapman and Peres, 2001; Kerr and Deguise, 2004). To conserve such threatened species, information on the population size, diet selection and foraging behaviour of species is very important (Sutherland, 1998). Blue monkeys as a species are not threatened (Lawes, 1990). However, the subspecies are highly localized and information on their basic biology, ecology and conservation is very limited (Oates, 1996; Kingdon et al., 2008). Boutourlini's blue monkeys (*Cercopithecus mitis boutourlinii*), is a forgotten subspecies endemic to the Southwestern Ethiopian Rift Valley between Lake Tana and Lake Turkana (Yalden et al., 1977; Butynski and Gippoliti, 2008). They had never been the subject of study, and thus their biology, ecology and social behaviour is unknown (Tesfaye et al., 2013). They are listed as Vulnerable by IUCN because of the severe destruction and fragmentation of forests (Butynski and Gippoliti, 2008). Currently, this subspecies is widely distributed in protected areas and remnant forest patches of the southwestern parts of Ethiopia. Studies on ecology, biology and behavioural patterns of Boutourlini's blue monkey are lacking. To ensure the efficiency of future conservation of Boutourlini's blue monkeys, it is important to study the ecology, biology and behaviour of this subspecies. The study of foraging behaviour is important to understand the adaptation of a species to its environment. The study of diet in particular can help to know population dynamics, habitat use and social organization of the species (Maruhashi, 1980). The present study, therefore, aimed to investigate the population size, habitat association and dietary composition of Boutourlini's blue monkey in Komto Protected Forest.

MATERIALS AND METHODS

Study area

Komto Protected Forest is located in Western Ethiopia in Oromia Regional State of East Wollega Administrative Zone. It is situated between 9° 05' 10" to 9° 06' 35" N latitude and 036° 36' 47" to 036° 38' 10" E longitude with an elevation ranging from 2,135 to 2,482 m asl (Mosissa et al., 2011). Komto Protected Forest is part of the National Forest Priority Area called Komto Wacha Tsige Protected Forest which is currently fragmented from the other parts of the forest by increased expansion of agricultural lands, overgrazing, encroachments and commercial harvesting of both natural and plantation forests. Currently, it has a total area of 1888.09 ha including both disturbed and undisturbed habitats (Figure 1). The study area falls within the southwestern and western unimodal rainfall region of Ethiopia with little or no rainfall in December, January and February. Rainfall gradually increases to peak from June to September. The mean annual rainfall of the area for 2002 to 2011 was 2143 mm. The mean minimal temperature was 12.1°C and the mean maximum was 28.1°C.

Description of habitats types

Komto Protected Forest is characterized by moist evergreen afromontane forest in which trees form an open canopy. The

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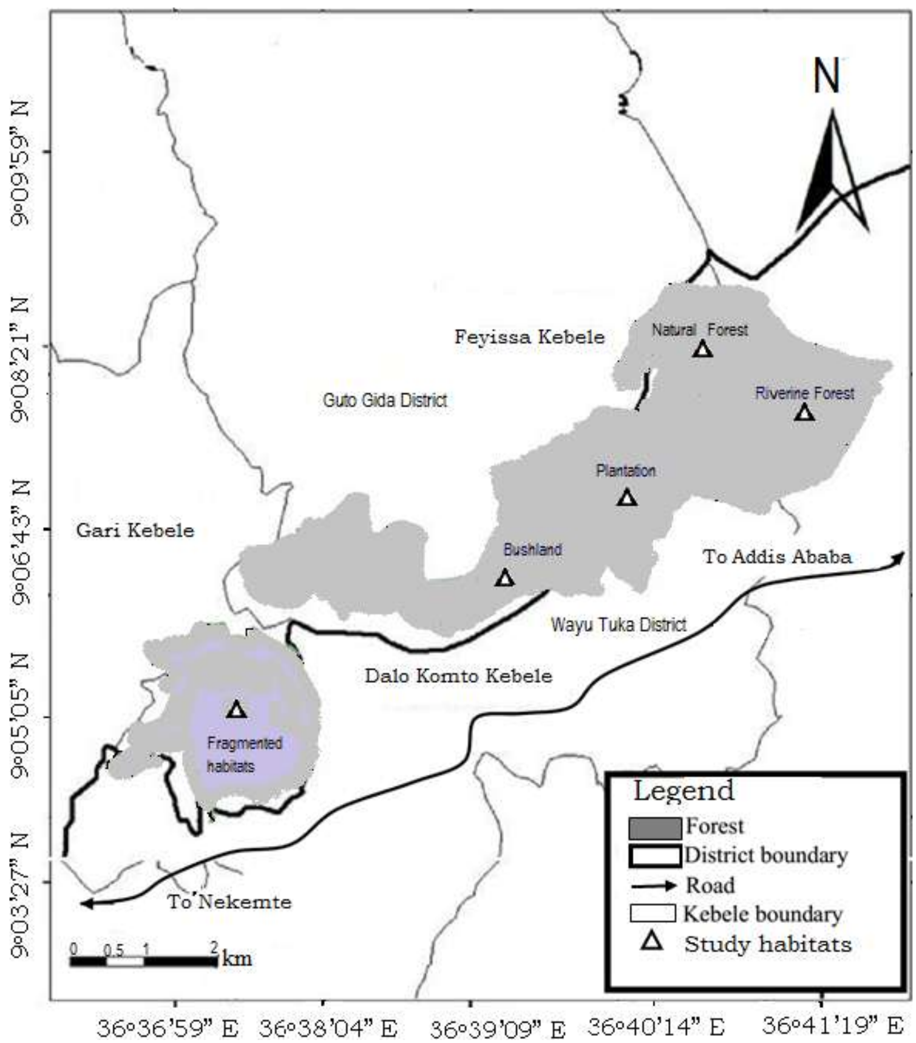

Figure 1. Map of Komto protected forest.

vegetation type of the study area consists mainly of natural and man-made forests. Komto Protected Forest consists of about 180 plant species belonging to 28 genera and 21 families. The forest contains about 18 plant species endemic to Ethiopia. Of all families, Fabaceae and Asteraceae dominant followed by Lamiaceae, Malvaceae and Poaceae (Fekadu et al., 2013). The species composition of plantation forest includes *Eucalyptus* spp., *Cupressus lusitanica, Grevillea robusta* and *Pinus radiata*. The study area was stratified into five habitat categories based on the vegetation types, structure and conservation status of the forest.

These include: Natural forest, riverine forest, bushland, plantation and fragmented habitats.

Data collection

Due to low density of Boutourlini's blue monkeys in the area, total counting method was used to determine their population size (Norton-Griffiths, 1978). The open nature and fragmentation of the forest made total counting Boutourlini's blue monkey easier. Five habitat categories were identified (natural forest, riverine forest, plantation, fragmented habitats and bushland) to assess Boutourlini's blue monkeys in the area. To ensure total counts, four individuals living adjacent to the forest were trained and assigned to each habitat type to simultaneously assess the locations of Boutourlini's blue monkey both during the dry and wet seasons. Assessment was conducted from 07:00 to 11:00 in the morning and 14:00 to 17:30 p.m. in the afternoon. The presence of Boutourlini's blue monkeys were detected only in natural and riverine forests. Detected troops were named as natural forest group (NF Group) and riverine forest group (RF Group). To minimize underestimation of population size, five transect lines were additionally used in the surrounding remnant forest patches. However, no Boutourlini's blue monkey troops were detected in the surrounding areas during both seasons. Accordingly, counting of Boutourlini's blue monkeys was carried out in the two habitats. During counting, individuals located at distances of between 20 and 30 m from one another were considered as one group. To study the foraging behaviour of Boutourlini's blue monkeys, the natural forest group was selected for detailed study. The group was selected because they are easily accessed compared to the riverine forest group. The riverine group was excluded due to inconveniences of steep slope of the area to follow the group. The groups were identified by their habitat types and total number of individuals that made the troop. In addition, the groups were about 300 m part from each other.

Dietary data were collected for 58 days covering both the dry

Table 1. Population size of Boutourlini's blue monkeys in Komto protected forest.

	Total size	Sex	Adults	Sub-adults	Juveniles	Infants
		Male	2	3	2	-
NF	17	Female	6	2	-	-
		Unknown	-	-	-	2
		Male	1	2	1	
RF	12	Female	4	2	-	
		Unknown	-	-	-	2

NF, Natural forest; RF, Riverine forest.

(January-March, 2015) and wet (July–September, 2015) seasons. Scan sampling method (Altmann, 1974) was used to collect data on the foraging behaviour of multiple group members. Scan sampling was conducted at 15 min intervals between 07:00 a.m. and 11:00 with an observation period lasting for 5 min. Observation of all visible adults and sub-adults in the focal groups were carried out early in the mooring starting from their roosting sites until they disappeared from sight. Scanning was carried out interchangeably from left to right for the first scan and then from right to left for the second to minimize the risk of recording the same animal twice or being biased by recording the most obvious animals (Abernethy, 2000). Close habituation to the focal group was not successful as humans had chased them during illegal logging over longer periods. Due to this, the troop was partially habituated and scan sampling was conducted using unaided eyes and or binoculars from a distance of approximately 30 to 40 m during the wet and dry seasons, respectively.

Foraging is defined as ingesting food items, manipulating (with the hands or mouth), carrying (in the mouth) and searching for food items using visual scanning in combination with grasping or searching with arms (Bunce et al., 2011). Food capturing techniques of monkeys were mainly classified as grabbing (quickly and easily capturing the prey or food with one hand), catching (grasping and or holding food with two hands and eating), pulling (exerting strong force to cause movement of food towards itself) and mouth grabbing (removing food items with mouth alone) (Baum, 2005; Nekaris, 2005). Monkeys used these methods of food extraction depending on the distance, types and strength of branches where food items were located (Baum, 2005). Capturing as food acquisition techniques was mostly used when the monkeys have appropriate sit at the middle of tree branches whereas grabbing was used when they are found closer to the terminal branches. Grabbing with mouth was used as food acquisition techniques when monkeys sat in many branches with thick foliages. However, pulling was mostly used when they feed attempts to feed on strong and unreached tree branches. Therefore, during scan sampling, mechanisms of food extractions (grabbing, catching, pulling and mouth grabbing) were recorded only from the adults and sub-adults assuming that juveniles and infants often learn from adults and sub-adults (Baum, 2005). In addition, food items and types of plant species consumed were recorded. Food items were recorded as young leaves, mature leaves, flowers, fruits, seeds, shoots, barks and unknown (when unknown plant parts or animal matters were consumed) (Fairgrieve and Muhumuza, 2003; Di Fiore, 2004). Identification of most plant species in the forest was easier as the species composition of the forest was studied (Fekadu et al., 2013). However, unidentified plant species, during the study periods, were collected and identified by an expert. Consumption of animal matters were recorded when a monkey was observed scratching tree barks and searching, and exposing curled leaves or ingesting invertebrates (Dietz et al., 1997).

Data analysis

Diet composition was evaluated by calculating the proportion of different food items and species consumed by the monkeys. The daily food items and type of species consumed by the groups was summed to calculate seasonal proportion of food items and food types consumed (Abernethy, 2000). The relative proportion of plant species used as food was calculated from the seasonal percentage contribution of different species (Fashing, 2001; Di Fiore, 2004). To get the percentage of food item foraged from each plant species, each foraged plant species and food item was summed per species. And, the percentage of each food item was calculated related to all food items per individual plant species. To determine the percentage utilization of a species, the total number of sightings of feeding on a forage species was divided by the total number of sightings for all species eaten (Abernethy, 2000). The total number of observations and frequencies were calculated for food extraction methods. Chi-Square analyses were used with SPSS V17.0 with probability set at the 0.05 level of significance.

RESULTS

A total of two groups and 29 Boutourlini's blue monkeys were recorded in Komto Protected Forest (Table 1). Among these 17 individuals were recorded in natural forest and the remaining 12 were recorded in the riverine forest. The difference in the number of individuals observed between the two habitats was not significant (χ^2=0.18, df=1, P>005). From a total of 29 Boutourlini's blue monkeys recorded in the area, females and males constituted about 48.28 and 37.93%, respectively. Adult females comprised (41.38%) followed by sub-adult males which accounted for 17.24% of the total population. Adult males and infants of unknown sex comprised 10.34 and 13.79%, respectively.

The comparative use of different habitat types by Boutourlini's blue monkeys in Komto Protected Forest was indicated by the number of individuals observed in each habitat type. Natural forest was utilized both during the dry (60%) and wet (58.62%) seasons. Riverine forest was the second habitat type utilized during both seasons. However, Boutourlini's blue monkeys did not use bushland, plantation and fragmented habitats. The variation in the number of Boutourlini's blue monkeys observed in different habitats types was significant

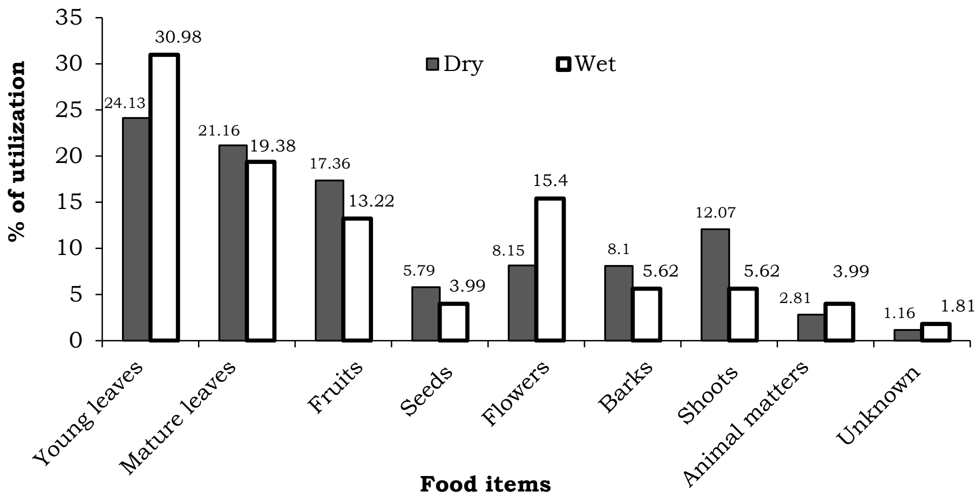

Figure 2. Percentage of food consumed by Boutourlini's blue monkeys during the wet and dry seasons.

(χ^{2}=82.86, df=4, P<0.05).

A total of 1157 feeding observations were recorded from a total of 2320 scan samples carried out during the two seasons. A total of 21 plant species, animal matters and unknown food items were consumed by Boutourlini's blue monkeys. The majority of feeding were recorded for young leaves (27.40%) followed by matured leaves (20.30%) and fruits (15.38%). About 3.37% of the total consumed food constituted by animal matters. Some food items were recorded as unknown (1.47%) as consumed items were not easily recognized. Feeding recorded for the male and female individuals accounted for 55.22% (N=639) and 44.77% (N=518), respectively. The total feeding recorded for Boutourlini's blue monkey during the dry season (N=605) 49.96% was slightly greater than the wet season (N=552) 49.35%. But there is no significant variation in the number of feeding observation recorded between seasons (χ^{2}=0.15, df=1, P>0.05) but the difference was significant between males and females (χ^{2}=12.65, df=1, P<0.05).

Among plant parts consumed as food, the percentage of feeding on matured leaves (21.16%), fruits (17.36%), seeds (5.79%), barks (8.10%) and shoots (12.07%) were higher during the dry than the wet season, 19.38, 13.22, 3.99, 5.62 and 5.62%, respectively. However, the percentages of feeding recorded for young leaves (24.13%) and flowers 8.15% were low during the dry season but increased to 30.98 and 15.40% during the wet season, respectively (Figure 2). Feeding recorded for animal matters are also slightly greater during the wet season (3.99%) than the dry season (2.81%). Stems and roots were not observed being consumed during any of the feedings. There was no significant difference in the utilization of young leaves (χ^{2}=1.97, df=1, P>0.05), matured leaves (χ^{2}=1.88, df=1, P>0.05), seeds (χ^{2}=2.96, df=1, P>0.05) and animal matters (χ^{2}=0.64, df=1, P>0.05) between seasons. However, the utilization of bark (χ^{2}=4.05, df=1, P<0.05), shoots (χ^{2}=16.96, df=1, P<0.05), fruits (χ^{2}=5.75, df=1, P<0.05) and flowers (χ^{2}=12.31, df=1, P<0.05) showed significant difference between seasons.

Boutourlini's blue monkeys consumed a total of 21 plant species belonging to 18 families. Among the total consumed species, 61.90% belong to trees and the remaining species were shrubs (19.05%), climbers (9.52%) and epiphytes (4.76%). Boutourlini's blue monkey mostly relied on young leaves, mature leaves and fruits. Young leaves were the principal food item consumed by this species. Family Rosaceae contributed 4 species for the diet whereas the remaining families were represented by one species each (Table 2).

The top ten most consumed plant species accounted for 79.85% of the overall diet of Boutourlini's blue monkeys (Figure 3). *Syzygium guineense* was the most consumed plant species which accounted for 16.68% of their diet followed by *Ficus sur* (13.13%) and *Prunus africana* (12.01%). Among the top ten species, six of them belong to trees. The remaining three and one species belong to shrubs and climbers, respectively. The most utilized shrub species accounted for 30% of top ten consumed plant species.

Among different types of foraging behaviour of Boutourlini's blue monkeys, the most utilized method was capturing and manipulating food with the aid of two hands. This method exhibited 47.97% of total feedings records (N=555) out of which males accounted for 50.23 % (N=321) and females 45.17 %(N=234). Grabbing foods 31.46% (N=364) and acquiring food by pulling accounted for 11.93% (N=138) which were the second and third food acquisition techniques, respectively. There was significant difference between the four types of food acquisition techniques by Boutourlini's blue monkeys (χ^{2}=387.57, df=3, P<0.05). However, there was no

Table 2. Plant species and parts consumed by Boutourlini's blue monkeys in Komto protected forest.

Habit	Family	Plant species	Parts eaten	Feeding record	% of utilization	Local name
Tree	Myrtaceae	*Syzygium guineense*	YL,ML,FR	193	16.68	Baddeessaa
Tree	Moraceae	*Ficus sur*	BA, FR, YL	175	13.13	Harbuu
Tree	Rosaceae	*Prunus africana*	SH, BA,FR	139	12.01	Goraa
Tree	Meliaceae	*Ekebergia capensis*	SH, YL, BR, FR	103	8.90	Hoomii
Tree	Myrsinaceae	*Embelia schimperi*	YL, ML,FR	102	8.82	Haanquu
Shrub	Rosaceae	*Rubus apetalus*	FL, FR	60	5.19	Goraa arbaa
Shrub	Rosaceae	*Rubus steudneri*	FL, FR	52	4.49	Waddeessa
Tree	Boraginaceae	*Cordial africana*	FR, SE	47	4.06	Somboo
Shrub	Rosaceae	*Rosa abyssinica*	SE, FR	41	3.54	Qagaa
Climber	Urticaceae	*Urera hypselodendron*	SH, FL	35	3.03	Laanqessaa
Tree	Rubiaceae	*Rytigymia neglecta*	YL, ML	31	2.68	Mixoo
Climber	Ranunculaceae	*Clematis hirsute*	YL	26	2.25	Hidda fiitii
Tree	Rutaceae	*Vepris dainellii*	FR	23	1.99	Hadheessa
Tree	Fabaceae	*Albizia gummifera*	SE	19	1.64	Mukarbaa
Tree	Apocynaceae	*Carissa spinarum*	SE, FR	15	1.30	Agamsa
Tree	Flacourtiaceae	*Dovyalis abyssinica*	YL,FR	13	1.12	Koshimii
Tree	Dracaenaceae	*Dracaena steudneri*	FR	10	0.86	Warqe Qamalee
Tree	Euphorbiaceae	*Croton macrostachyus*	BA, SE	7	0.61	Bakkanisa
Shrub	Crasulaceae	*Kalanchoe densiflora*	YL, SH	5	0.43	Bosoqqee
Shrub	Tliaceae	*Triumfetta rhomboidea*	FR	3	0.26	Hincinnii
Epiphytes	Loranthaceae	*Phragamanthera macrosolen*	SH	2	0.17	Dheertuu

FL, Flowers; FR , fruit; ML, mature leaves; SE, seeds; YL, young leaves; SH, shoots; BA, barks.

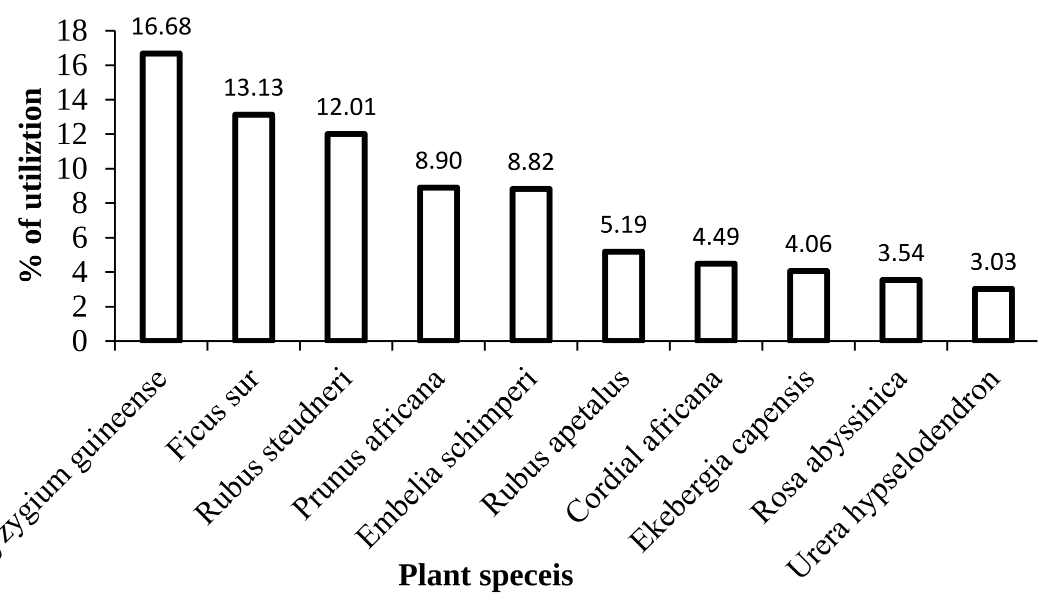

Figure 3. Top ten plant species utilized by Boutourlini's blue monkeys in Komto Protected Forest.

significant difference in grabbing (χ^2 =7.43, df=3, P>0.05), pulling (χ^2=4.17, df=3, P>0.05) and mouth grabbing (χ^2=0.36, df=3, P>0.05) as food acquisition methods between male and females. Catching as food acquisition method varied significantly between males and females (χ^2=13.64, df=3, P<0.05).

DISCUSSION

The remnant forest patches around mountainous and riverine forests of Western Ethiopia serve as a good refuge for Boutourlini's blue monkeys. However, the biology, ecology and behaviour of this subspecies have not been studied (Tesfay et al., 2013). Hence, the findings of this study are mostly compared with other guenons and similar subspecies studied in other African countries. Boutourlini's blue monkeys were recorded only in the natural and riverine forests of Komto Protected Forest. As described by Leighton (1993), they prefer matured forest due to the existence of sufficient fruit and structural features that assists arboreal movement. The number of Boutourlini's blue monkeys recorded increased from 15 to 17 in the natural forest and from 10 to 12 in the riverine forest. This increment was attributed to birth during the wet season. Similar finding was reported from Jibat Forest, Ethiopia by Tesfaye et al. (2013). The population size of Boutourlini's blue monkey recorded during the present study was very low which might be attributed to anthropogenic activities that resulted in reduction of food sources in the area. As reveled by Kempe (2008), frugivorous primates are shown to be very sensitive to forest clearings as it may reduce the population due to scarcity of food. According to Chapman and Chapman (2002) and Wallace et al. (1998), the abundance and density of primates were related to food quality and availability. Similarly, continuing decline in the number of blue monkey has been observed in the Kibale National Park, Uganda due to large timber cuttings (Chapman et al., 2000). Blue monkey was unable to cope with the increasing rate of deforestation and habitat fragmentation in Africa (Lawes and Chapman, 2003).

Though blue monkey are adapted to live in varieties of forest habitats (Kingdon, 1971; Estes, 1992), they are occasionally observed foraging on the ground across open habitats (Stuart, 1997). However, they reject bushland, fragmented habitats and plantation forests in Komto Protected Forest. This might be linked with the severe disturbance, poor shelter and scarce food in these habitats. In addition, Boutourlini's blue monkey might avoid open habitats due to attacks of predators as witnessed by Jaffe and Isbell (2007). Blue monkey can be found in forest fragments if and only if they are survival groups originating from periods with larger forests rather than newly immigrated animals (Kempe, 2008).

The diet of blue monkeys comprises a few plant species (Fairgrieve and Muhumuza, 2003). This is also the case during the present study in which most food items were consumed from a few plant species. Among the 21 plant species consumed by Boutourlini's Blue monkeys, the top ten consumed plant species accounted for 79.85% of their overall diet. This might be linked to the preference of larger trees for sheltering and predator avoidance as humans frequently visit the forest for timber production. *Syzygium guineense* is the most foraged plant species in the study area. This is because the tree possesses dense and evergreen foliage throughout the year with more foliage observed during the dry season. *Ficus sur* is the second most preferred plant species in the study area. Similarly, *C. m. stuhlmanni* utilized Ficus species in Masai Mara National Reserve in Kenya (Kempe, 2008). To the contrary, feeding on shrubs, herbs and climbers was insignificant because the area was under high human pressure due to various anthropogenic activities. In addition, such plant species are closer to the ground, and might expose them to predation. As stated by Kempe (2008), large trees were used by monkeys both for foraging and positioning high above the ground to protect potential predators.

The sources of food for guenons are as diverse as their habitats though they are selective feeders (Cords, 1986; Kaplin and Moermond, 2000). Blue monkeys are mainly frugivours but also eat leaves, flowers and insects based on availability (Cords, 2002; Fairgrieve and Muhumuza, 2003). However, Boutourlini's blue monkeys mostly utilize young leaves, mature leaves and fruits in Komto Protected Forest. Young and matured leaves have low cellulose and secondary toxic compounds that makes digestion easier (Cords, 1987). In addition, young and matured leaves provide a high percentage of crude protein and calcium, respectively (Rudran, 1978). Blue monkeys at Komto Protected Forest use young leaves, matured leaves and flowers more as food compared to other Cercopithecus spp. (Table 3). However, the amount of feeding recorded for fruits was less among the genus Cercopithecus. The reduction of fruits in the diet of Boutourlini's blue monkeys might be attributed to the shortage of fruits in the forest. In addition, the availability of leaves might be better than fruits in the study area. As stated by Kempe (2008), when fruits are less available in the habitat, they switch to feed on foliar foods. In addition, the foliar diets of frugivours monkeys is an indicator of adaptive lifestyle and periodic fluctuations of food resources.

Dietary flexibility can be resulted from habitat variation, relative abundance of food and food preference of blue monkeys (Rudran, 1978; Chapman et al., 2002). Boutourlini's blue monkey also consumed considerable amounts of fruits, seeds and flowers. Flowers were consumed more during the wet season. This might be linked to the increased production of flowers along within the rainy season. Flowers are generally high in sugar content, providing energy (Wasserman and Chapman, 2003). Seeds and fruits were consumed more during the dry season because flowers produced during the wet season produce fruits and seeds during the dry season. The three food items were seasonal and not available throughout the year. To the contrary, bark, shoots, mature leaves and animal matters were consumed more during the dry season than the wet season. As described by Linderoth (2008), the consumption of more bark during

Table 3. Percent of feeding records on different food items by members of the genus *Cercopithecus* in Africa.

Species	YL	ML	TL	FL	SH	FR	Am	SD	BA	Country and site	Reference
C. mitis boutourlinii	27.4	20.3	47.7	11.24	8.99	15.4	3.4	4.93	6.9	Komto Protected Forest, Ethiopia	This study
C. m. boutourlinii	14.4	3.9	18.3	7.0	20.6	32.4	13.8	5.7	1.6	Jibat Forest, Ethiopia	Tesfaye et al. (2013)
C. m. doggetti	-	-	6.2	6.2	-	47.4	24.9	9.3	-	Rwanda	Kaplin (2001)
C. ascanius	-	-	34.7	2.7	-	44.6	17.6	-	-	Kibale at Sebatoli, Uganda	Chapman et al. (2002)
C. ascanius	-	-	28.8	3.7	-	35.7	31.2	-	-	Kibale at Kanyawara, Uganda	Chapman et al. (2002)
C. nictitans	10.0	0.1	10.1	4.1	-	35.5	-	50.2	-	Gabon	Brugiere et al. (2002)
C. hoesti	-	-	35.2	4.0	-	24.5	8.8	17.8	-	Nyungwe Forest Reserve, Rwanda	Kaplin (2001)

YL, Young leaves; ML, mature leaves; TL, total leaves; FL, flowers; SH, shoots; FR, fruit; Am, animal matter; SD, seeds; BA, bark.

the dry season might be attributed to shortage of food. Shoots were utilized more during the dry season because of the low availability of foliage forcing them to feed on shoots. Matured leaves were also consumed more during the dry season though they are less palatable and assumed to have high secondary compounds (Rudran, 1978). This might be an adaptation of Boutourlini's blue monkeys to compensate for food and foliage shortage encountered during the dry season. As stated by Smith (1959), the use of a wide variety of food items is very important to maximize total food consumption. Animal matters such as insects and other invertebrates were used more during the wet season than the dry season. This might be due to the increased number of invertebrates and insects during the wet season. During the present study, males engaged in feeding slightly more than females on average. This might be due to the periodic exclusion of males from the group to live solitarily which decreases time wasted in socialization but increases time of feeding.

Young and matured leaves were utilized more than fruits which coincide with the diets of guenon monkeys being highly flexible, depending upon various conditions (Chapman et al., 2002; Fairgrieve and Muhumuza, 2003). Monkeys used different foraging strategies when feeding on plant parts or animal matters. Among the different methods of acquiring food, preference was shown by Boutourlini's blue monkeys to grasp and or holding food with two hands and then chewing. This accounted for 47.97% of the total feeding observation. The method might be used by the monkey to easily manipulate food items from branches. Catching method was used more by males than females because the hands of females are busy in handling young. The results of this study suggested that the forearms of females are relatively busy in handling infants, grooming and juvenile feedings. Grabbing was used when the food items are easier and closer to handle with one hand alone. Pulling as a foraging method is used when food items are difficult to reach, and need to pull branches holding food items towards them. Mouth grabbing is used as food acquisition technique when monkeys are positioning in branches having dense foliages closer to the mouth.

Threats

Destruction of trees for timber production, agricultural land expansions, encroachments, trampling and grazing pressure by livestock are serious threats for future existence of Boutourlini's blue monkeys and other mammals in Komto Protected Forest. Illegal charcoal and commercial timber production are the main threats for wildlife in Komto Protected Forest. Continuous removal of natural forest for timber, charcoal and construction materials will result in a sudden collapse of the forest and local extinction of Boutourlini's blue monkey. Over the last ten years, plantations of seedlings have been carried out in Komto Protected Forest with no evident positive change on the status of the forest. This is because seedlings planted around the edge of the forest have very low survival rate due to trampling by livestock. Community information reveals that the numbers of Boutourlini's blue monkeys in Komto Protected forest are dwindling. Currently, Boutourlini's blue monkeys are restricted to natural and riverine forests. Such restricted preference of narrow ecological niches might lead Boutourlini's blue monkeys to local extinction in Komto Protected Forest. Large trees are selectively harvested for illegal timber production in Komto Protected Forest. This will directly affect Boutourlini's blue monkeys as large trees are preferred for roosting, feeding and predator avoidance. The current status of Komto Protected Forest is not promising for the future survival of mammals in general and Boutourlini's blue monkeys in particulars unless special conservation action is designed to conserve Komto Protected Forest.

Conflict of interests

We have no conflict of interest.

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