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Full Length Research Paper

Diversity of lichens at Mount Cameroon, South West Region, Cameroon

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Concern about maintaining the biodiversity of lichen communities' species has been an issue with lichenologists for many years. Many of the understudied regions face increasing threats from urban development, pollution, and potentially climate change, among other factors. The objective of this study was to examine the diversity of lichens on Mt. Cameroon. To achieve this objective, eight collection sites were surveyed on two flanks of the mountain at elevations ranging from 3 to 2178 m above sea level. The visual estimate sampling method using circular plots was adopted for the survey. Voucher specimens were collected in triplicate and deposited in the herbaria in Limbe and the University Buea. Lichens were identified by studying the morphology and chemical spot test. The morphology of the thallus and reproductive structures were examined under the stereomicroscope at 10×. The K-test, C-tests and KC-spot test were performed for each specimen with KOH and $Ca(OCl)_2$. The abundance rating scale, species diversity, similarity and richness indices were computed. Identification by molecular, morphological and chemical spot tests produced a total of 89 species, 22 site-specific species, 52 genera belonging to 27 families and 11 orders. Four lichen specimens were identified to genus level and eighty-five to species level. According to the Cameroon lichen database, 82 of these are new discoveries. Parmeliaceae, *Heterodermia, Usnea* and *Dirinaria applanata* dominated the area. The identified species occurred in six growth forms and from nine substrates types. Foliose and corticolous lichens were most represented. Among the sites surveyed, Upper Buea situated on the leeward flank at high altitude >1000 m, recorded the highest diversity and site-specific species.

Key words: Lichens diversity, Mt. Cameroon, Upper Buea Leeward flank.

INTRODUCTION

The lichen mycobiota in several areas of the world especially in the tropics is still under-explored (Feuerer and Hawksworth, 2007). Many of the understudied regions face increasing threats from urban development, pollution, and potentially climate change, among other factors (Bjerke, 2011). Concern about maintaining the biodiversity of lichen communities' species has been an issue with lichenologists for many years (Will-Wolf et al., 2006). This is observed over 100 years ago with effects of air pollution and expanding in the last 50 years to

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include effects of climate change (Ellis, 2019), deforestation, land management, fragmentation of natural habitats and loss of biodiversity. With the loss of sensitive lichen species from Europe and America due to the high rate of deforestation, global climate change and air pollution (Rocha et al., 2019), lichenologists are emphasizing the need to catalogue lichen species before their natural diversity is lost and to create 'protected areas' for their conservation (Jovans, 2008).

Accurate identification of lichen species is crucial to effectively assess biotic diversity, species' response to disturbance in monitoring programs and implementation of effective conservation management strategies in an area (Giordani and Brunialti, 2015**).** An effective monitoring program depends on complete and accurate inventory information about the full extent of the species assemblage within an area (McClenahen et al., 2007). Thus, rapid inventories of lichen taxonomic diversity assessment achieved by morphological, anatomical, chemical, and molecular identification (Lumbsch et al., 2011) are particularly relevant. Nevertheless, while DNA-based molecular identification may be successful in areas where lichens are well studied (Kelly et al., 2011), it is not for underexplored areas like Mt. Cameroon (Orock et al., 2012).

Compared to tropical America and South East Asia, the lichen flora of tropical Africa is insufficiently known and that of western Africa is largely unknown (Feuerer and Hawksworth, 2007). Urgent survey is required in the countries within these regions to obtain data on lichen status with focus on rare and declining species found in the world red- list of lichens. Currently, only 101 lichenized fungal species are listed for the Republic of Cameroon, West Africa (Feuerer, 2011). However, floristic surveys of lichenized fungi in an important ecological area like Mt. Cameroon are lacking. Mount Cameroon area with extensive biodiversity is often threatened by volcanic eruptions and deforestation. This volcano with a return period of 20 years (Suh et al., 2003), has had the most frequent eruptions than any other West African volcano with eight eruptions in the last 100 years (1909, 1922, 1925, 1954, 1959, 1982, 1999, and 2000). Also, human-related activities are fragmenting, degrading, and isolating the remaining forest patches despite conservation efforts. It is therefore necessary to know the different lichen species remaining around Mt. Cameroon after various eruptions and alarming deforestation rates. The objectives of this work are to assemble a checklist of lichens at Mt. Cameroon.

MATERIALS AND METHODS

Study area and sites

Mount Cameroon is located between 4° North and 6° 20' North latitude and 8° 50' East and 10° East longitude in the Southwest region of the Republic of Cameroon, on the coastal belt of the Gulf of Guinea (Figure 1). It covers a land surface area of approximately 24, 900 km^2. It is the highest mountain in Central and West Africa, rising up steeply from sea level to 4100 m at the summit (Suh et al., 2003).

This region of the Republic of Cameroon has an average annual rainfall of 4000 mm which declines inland to 1800 mm. Mean temperatures are around 20°C varying with the effects of elevation. Soils are andosols supporting lowland submontane and montane tropical forests, and a microcosm of tropical plantation agriculture. In White's phytogeographical classification (1983), the area falls within the afromontane eco-region (Ndenecho, 2009). Human-related activities are fragmenting, degrading, and isolating the remaining forest patches despite conservation efforts.

Sampling procedures

This study was carried out in 8 sites, located in ecologically diverse sites of Mt Cameroon, at elevations ranging from 3 to 2178 m above sea level (Figure 1). The study sites and their characteristics are presented in Table 1 and they constitute a general representation of the study area. However, some important habitats remain un-sampled, including sub-alpine and alpine habitats near the mountain summit.

Sampling procedures

The lichen survey consisted of a visual estimate and opportunistic random sampling method described by Jovans (2008) and McClenahen et al. (2007). This sampling method employs the concept of fine focused searches, looking in areas where high diversity is expected. These methods were selected based on their ability to maximize the detection of species diversity. At each sampling point, a circular plot of about 30 m radius with four (04) macro sub circular plots within was created (Figure 2). Each macro subplot was 20 m radius from its centre. In each macro plot, micro plots of 10 m radius from their centre were created. The distance between sub-macro plots centres was 30 m.

Sampling was done from each micro subplot to macro subplots from plot 1 to plot 4 systematically.

A total of 50 plots were sampled with a minimum of 5 plots per site, except for Lower and Upper Buea where 10 plots each were sampled because of their vast surface area. The chosen plots received a numbered identification plate and the precise positions were marked with a Global Positioning System (GPS). Lichens were observed, and measured in the field. Specimens were collected from live and dead tree barks, fallen branches, twigs, rocks and soil substrates in triplicate. Live trees were sampled from the base to about 2.0 m above the ground. For canopy sampling, some small twigs were cut with a secateurs and falling branches and twigs were sampled. A knife was used to remove lichens from the live and dead branches and twigs of trees. A hammer and chisel were used to remove lichens on rocks, while specimens on the soil were collected with the hand. All the substrates were examined using magnifying lenses of (x10) for morphological identification. Pictures of all specimens collected were taken using a NikonD80/D40 professional digital camera and produced in Buea, Cameroon used for identification. The specimens on wet barks were kept in plant press and tied tightly to avoid curling up. Each specimen was placed in a paper envelope and labelled with appropriate tracking and identification information. A number code such as Sp1, Sp2…. for example, was assigned to the specimens. Quantitative evaluation of lichen species was noted using the abundance rating frequency scale by Jovans (2008). Species were

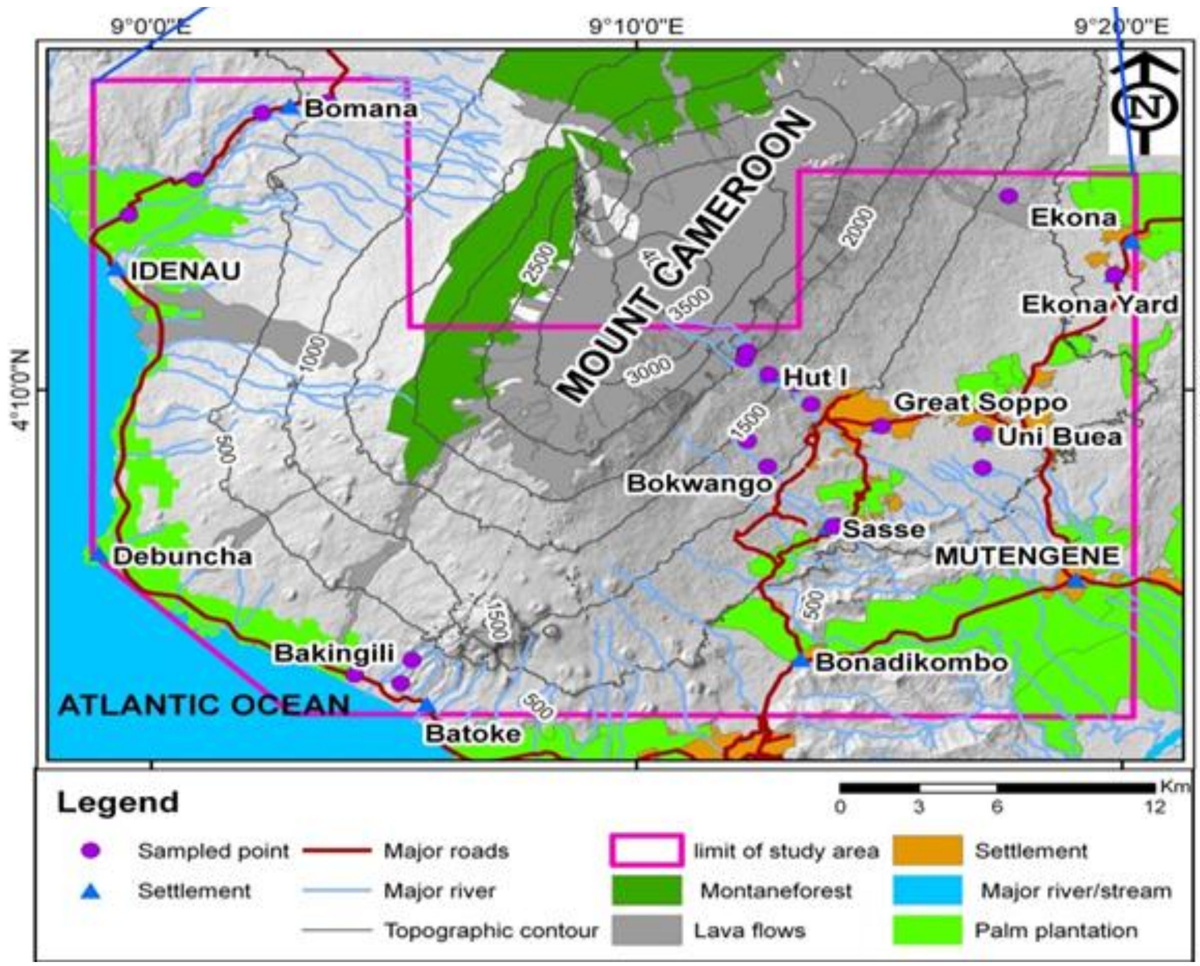

Figure 1. Topographic features of Mt. Cameroon and location of sampling sites mentioned in the text.

Table 1. Characteristics of the sampling sites for Lichens in Mt Cameroon.

Main site	Study sites	Site characteristics					
		Latitude	Longitude	Altitude (M)	Temperature (°C)	Light intensity (Lux)	Relative humidity (%)
Leeward site	Ekona Mbegue	14° 09′ 1″ N	18° 29′ 9″E	504.6±6.1	28.6±0.4	1846.2±4.4	79±1.0
	IRAD Ekona	12° 48′ 8″N	19° 50′ 3″E	416.3±8.1	29.0±0.4	1805.6±4.3	77±2.2
	Upper-Buea	10° 56′ 2″N	12° 16′ 7″E	1830.2±6.1	27.1±0.2	640.5±6.6	89±2.2
	Lower Buea	08 ° 56′ 3″N	17° 07′ 3″E	750.8±7.2	29.7±0.4	1630.6±5.5	89±3.1
Winward site	Batoke	02° 00′ 2″N	05°° 49′ 9″E	156.4±6.7	30.5±1.0	658.8±6.1	83±2.0
	Bakingili	03°17′4″N	03° 40′ 2″E	173±7.8	30.9±0.2	1706.9±5.6	83±1.0
	Idenau	14° 15′ 8″N	59°° 31′ 8″E	124.4±4.3	30.9±0.5	1454.5±4.5	83±3.0
	Bomana	17° 01′ 3″N	03°° 38′ 0″E	507.7±3.4	29.8±0.3	1452.8±5.1	80±3.1

Values of altitude, temperature, light intensity and relative humidity are means of 3 readings± standard deviation.

classified as rare (1 -2 individuals in the sampling unit), uncommon (3-5 individuals in the sampling unit), common (6-10 individuals in sampling unit) and abundant (>10 individuals in sampling unit).

Processing specimens for identification

All the specimens brought from the field were taken to the

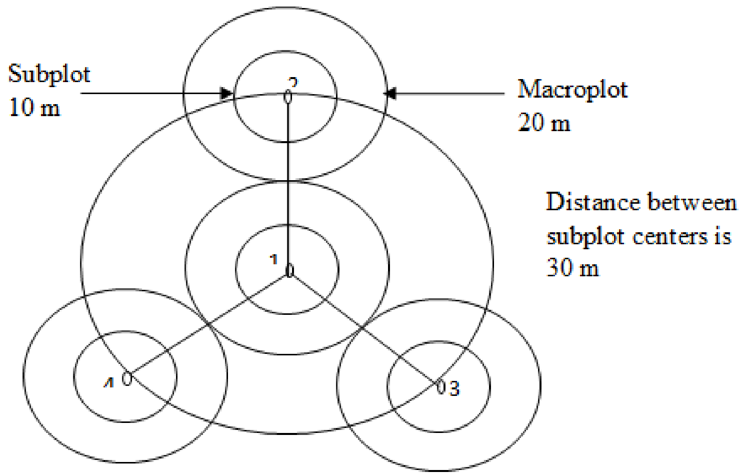

Figure 2. Outline of Lichen sampling technique for each site.

University of Buea Life Sciences Laboratory. The specimens were sorted, curated and prepared for drying. The specimens were dried in an oven at 60°C for 6 h. The dried specimens were then placed inside herbarium bags. Crust-like specimens on rock and wood/bark were glued using acid free herbarium glue. Fragile foliose specimens were placed between folded pieces of cotton padding for extra protection inside the envelope. The specimens were placed in the freezer for four days, to kill any insects, before being stored in the herbarium. Three voucher specimen packets were prepared and one packet each was deposited in the herbarium of the Botany laboratory of the University of Buea Cameroon and the Herbarium of the Limbe Botanic garden Cameroon.

Data analysis

Specimens were identified to generic and species level with the aid of "artificial field keys'' and by extensive matching with correctly identified specimens from herbaria and pictorials from online databases. Microscopic observations of free-hand sections of thallus and fruiting bodies were also made on some of the lichens in order to assess diagnostic characters provided in the keys. Chemical spot tests were carried out to distinguish some species of lichens using freshly prepared calcium hypochlorite, 10% aqueous solution of potassium hydroxide and freshly prepared paraphenylenediamine. Color reactions of the thallus to the above chemicals were observed by applying a small drop to the cortex on the upper surface or to the medulla after scraping off the cortex to expose the medulla. Lichens were preserved in packets by oven drying at 60°C for 6 h. Each specimen was transferred to a new envelope and information such as the name, family, site, altitude, tree species, recorders' names and date of collection were recorded on the envelope.

The morphological and chemical spot test observations were compared to keys of Coppins (2002), Brodo et al. (2001), May et al. (2000), St. Clair (1999), illustrations of St. Clair (1999), Goward et al. (1994), Goward (1999), and manuals of Gilbert (2004) and St. Clair (1999). The identity of each specimen was confirmed at the Herbarium of Nonvascular Cryptogams at Brigham Young University, Utah, USA.

Descriptive statistics were used to analyze the morphological and chemical identification data. Species diversity, richness and similarity were determined using Shannon-Weaver diversity index (H'), Margalef species richness index (D) and the Sørensen coefficient (Ss), respectively. All analyses were done with Microsoft Excel 2007, Inc, US 19.

RESULTS

A total of 89 lichen specimens were identified (Appendix 1). Four of the specimens were identified to genus level and eighty-five to species level. The lichens were identified in 27 families (Figure 3). Of these families, Parmeliaceae with 22 species was most represented followed by Physciaceae with 17 species. Twelve families of the lichen samples identified were represented by only one species each.

The lichens species identified from Mt. Cameroon belong to 52 genera (Figure 4). The genus *Usnea* was the most represented with 07 species followed by *Heterodermia* with 06 species. 31% of the lichen species identified in the study area were rated as common, while 18% were rated as rare (Figure 5).

A total of 22 species cut across sites and altitudes (Table 2). The placodioid species *Dirinaria applanata* with 36 individiuals was the most represented followed by the crustose species *Graphis scripta* with 24 individuals. *Leptogium gelatinosum* and *Heterodermia obscurata* were the most represented foliose species, while the species *Caloplaca citrina* had the least individuals 10.

The highest lichen diversity (4.70) by Shannon-Weaver index was recorded from Upper Buea in the Leeward Flank and the lowest (2.41) from Idenau in the Windward Flank (Table 3).

Lichen species richness by Margalef index was highest on the leeward flank from Upper Buea with 29.7% and

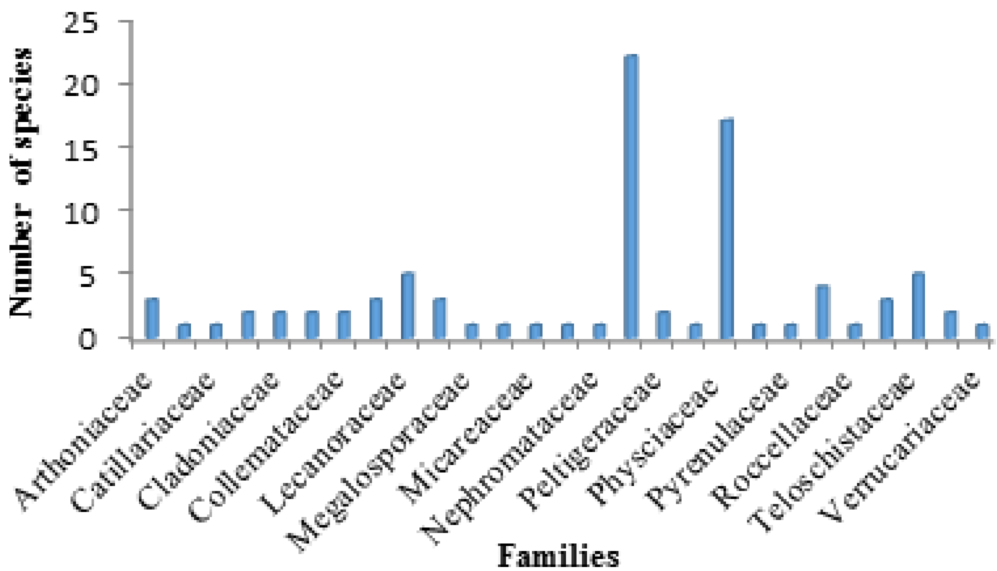

Figure 3. Abundance of lichen families on Mt. Cameroon.

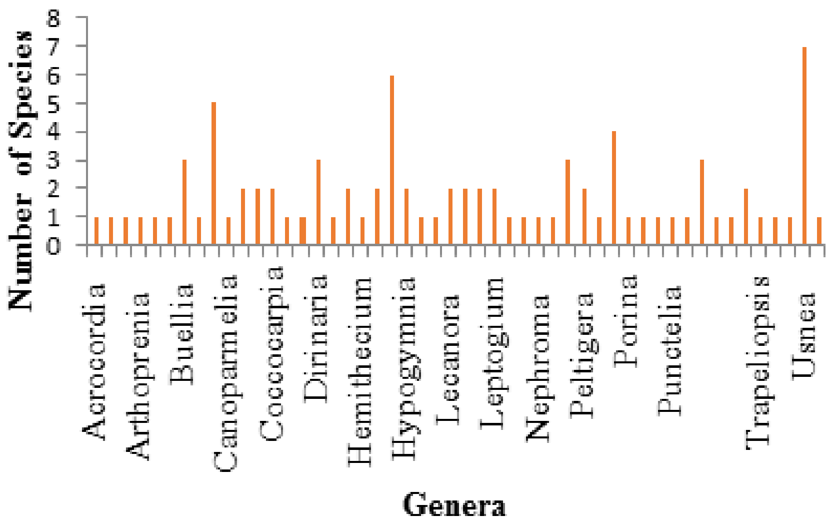

Figure 4. Abundance of lichen genera identified on Mt. Cameroon.

lowest on the windward flank with 8.3% from Idenau (Table 4).

From the Sørensen's coefficient of lichen species similarity, Batoke and Idenau on the windward flank show about 20% species similarity than any other sampling site in the study area (Table 5).

Distribution of lichen growth forms on Mt. Cameroon

Lichens from this study belong to six growth forms (crustose, foliose, fruticose, leprose, placodioid and squamulose). Foliose was the most represented with 35 species identified, while squamulose with 02 species was the least represented (Figure 6).

Distribution of lichen growth forms

Crustose, Leprose and Placodioid growth forms cut across all the sampling sites while fruticose growth forms were found at three sites (Ekona Mbenge, Lower and Upper Buea) (Figure 7).

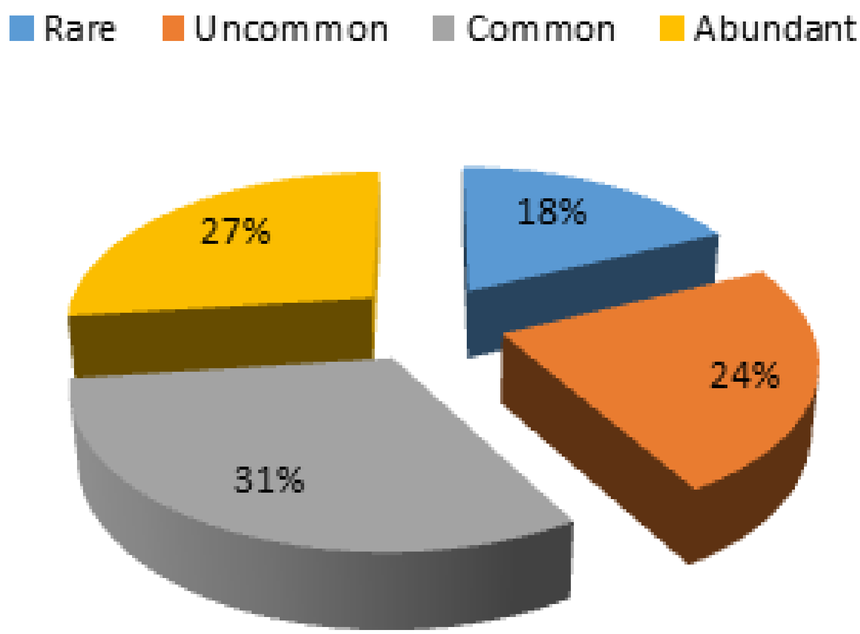

Figure 5. Abundance rating of lichen species identified on Mt. Cameroon.

Table 2. Lichen species identified that cut accross all sites, slopes and altitudes on Mt. Cameroon.

Species	Growth form	Individuals
Arthonia punctiformis	C	15
Aspicilia calcarea	C	14
Caloplaca citrina.	C	10
Caloplaca crenularia	C	16
Caloplaca microthallina	C	16
Catillaria nigroclavata	C	22
Cresponea permnea	C	17
Graphis elegans	C	16
Graphis scripta	C	24
Hemithecium rufopallidum	C	13
Lecidella elaeochroma	C	14
Porina heterospora	C	17
Pyrenula ochraceoflava	C	13
Thelotrema lepadinum	C	13
Heterodermia obscurata	Fo	17
Leptogium gelatinosum	Fo	19
Chrysothrix candelaris	Lep	16
Chrysothrix chlorina	Lep	17
Lepraria ecorticata	Lep	17
Lepraria obtusatica	Lep	13
Psilolechia lucida	Lep	21
Dirinaria applanata	Pla	36

C = Crustose; Fo = Foliose; Lep = Leprose and Pla = Placodioid.

Table 3. Shannon -Weaver Indices of lichen diversity at various sampling sites of Mt. Cameroon.

Main sites	Sub site	Shannon-Weaver index
Leeward	IRAD Ekona	2.82
	Ekona Mbenge	4.30
	Lower Buea	4.17
	Upper Buea	4.70
Windward	Batoke	3.49
	Bakingili	3.45
	Idenau	2.41
	Bomana	3.62

Table 4. Margalef Indices of lichen species richness at various sampling sites of Mt. Cameroon.

Main sites	Sub site	Richness index (%)
Leeward	IRAD Ekona	13.8
	Ekona Mbenge	17.5
	Lower Buea	23.7
	Upper Buea	29.7
Windward	Batoke	11.8
	Bakingili	12.3
	Idenau	8.3
	Bomana	13.0

Table 5. Sørensen's coefficient of lichen species similarity in various sampling sites of Mt. Cameroon.

Slope	Sites	IRAD Ekona	Ekona Mbenge	Lower Buea	Upper Buea	Batoke	Bakingili	Idenau	Bomana
Leeward	IRAD Ekona	1							
	Ekona Mbenge	0.39	1						
	Lower Buea	0.36	0.40	1					
	Upper Buea	0.45	0.35	0.34	1				
Windward	Batoke	0.47	0.49	0.39	0.34	1			
	Bakingili	0.46	0.48	0.38	0.33	0.57	1		
	Idenau	0.50	0.45	0.41	0.35	0.62	0.54	1	
	Bomana	0.46	0.45	0.46	0.38	0.56	0.55	0.60	1

Distribution of growth forms in different flanks

Out of the six growth forms identified in the study, no fruticose types were identified from the windward flank (Figure 8).

Crustose and foliose forms dominate all the different altitudes whereas no fruticose lichen was identified in the low altitude (Figure 9).

Distribution of lichen substrates

Lichens were identified from nine substrate types (Figure 10). Most species were corticolous lichens, while

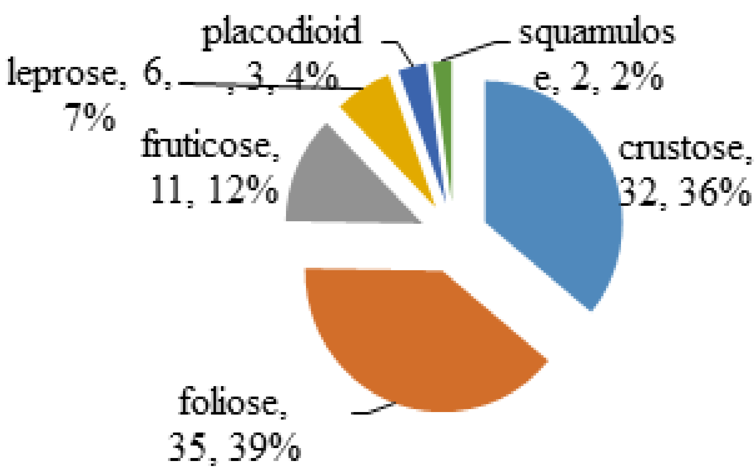

Figure 6. Distribution of lichen growth forms identified on Mt. Cameroon.

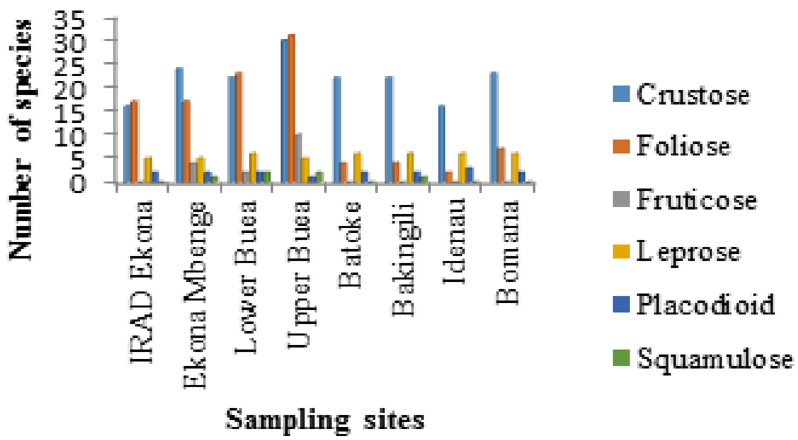

Figure 7. Distribution of lichen growth forms identified at different sampling sites on Mt. Cameroon.

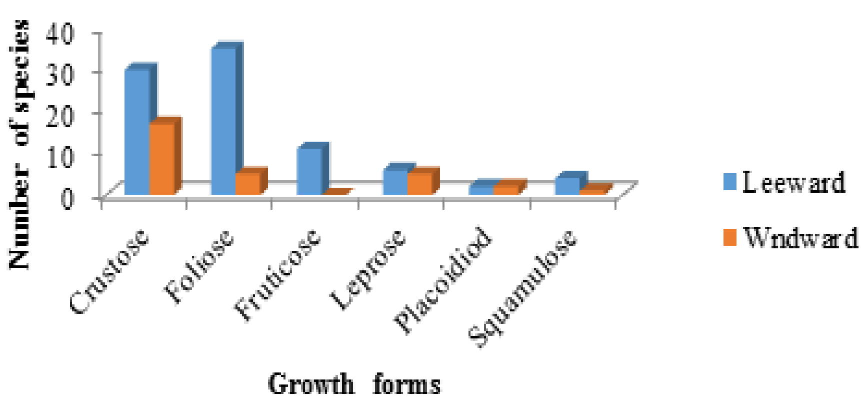

Figure 8. Distribution of lichen growth forms on different sampling flanks on Mt. Cameroon.

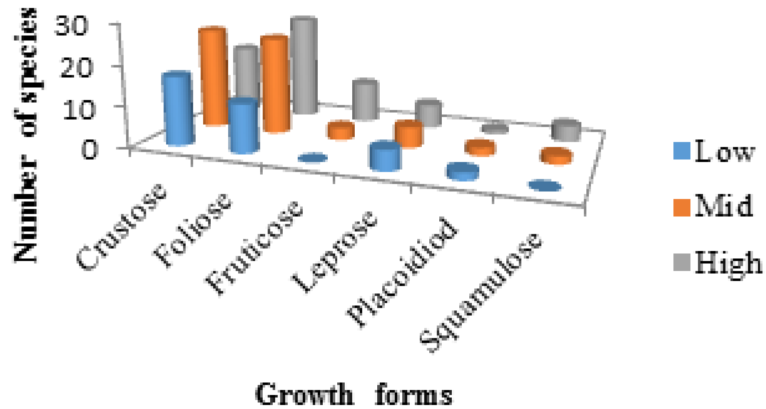

Figure 9. Distribution of lichen growth forms along different altitudinal ranges on Mt. Cameroon.

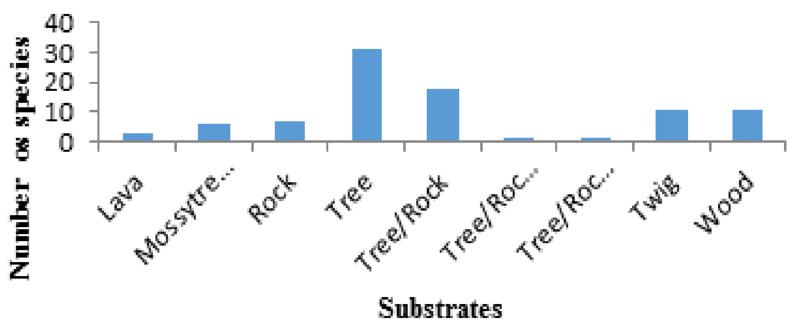

Figure 10. Distribution of lichen substrates on Mt. Cameroon.

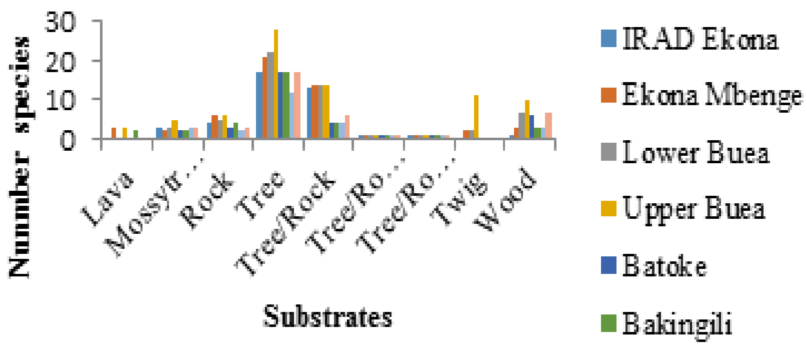

Figure 11. Distribution of lichen substrates at the different sampling sites on Mt. Cameroon.

tree/rock/soil and tree/rock/wood species were the least represented.

All the sampling sites were represented by corticolous, mossy tree/rock, tree/rock/soil and tree/rock/wood lichens (Figure 11). Ramicolous (twig) lichens were found only in Ekona Mbenge, Lower and Upper Buea.

Of the different lichen substrates, the leeward flank had all the ramicolous lichens and none was recorded at the

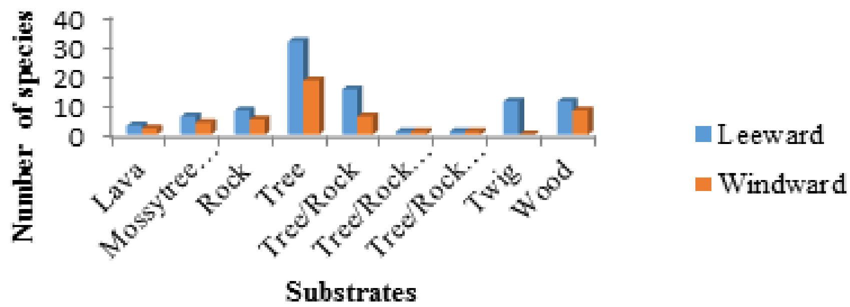

Figure 12. Distribution of lichen substrates at the different sampling flanks of Mt. Cameroon.

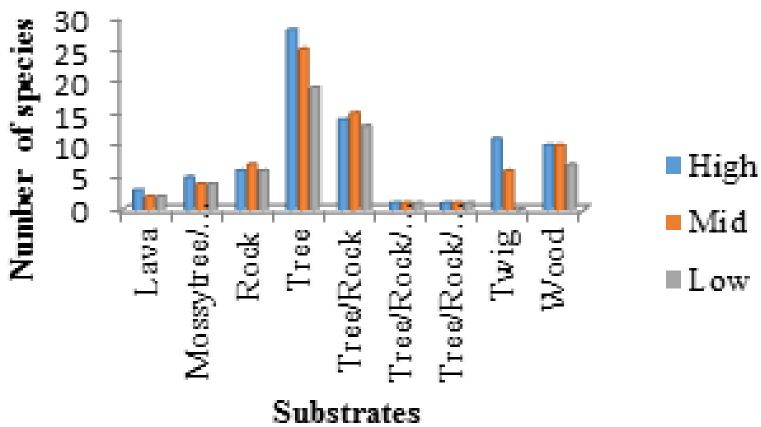

Figure 13. Distribution of lichen substrates at the different sampling altitudes on Mt. Cameroon.

windward flank (Figure 12).

Distribution of substrates along different altitudes

Eight of the nine different substrates were represented in the three altitudes (Figure 13). Ramicolous lichens were absent in the low altitude.

Distribution map of site-specific lichen species of Mt. Cameroon

Of the 89 lichen species identified from Mt. Cameroon, 22 were site-specific (Figure 14). 17 of these species were restricted to Upper Buea, 2 to Ekona Mbenge and one each to Great Soppo in lower Buea, Bakingili and Idenau.

According to this inventory, out of the 89 lichen species identified, 07 were common with that of Feuerer (2011), while 82 were not found and are therefore added as new species records for Cameroon (Table 6).

DISCUSSION

Among the sites surveyed at Mt Cameroon, Upper Buea situated on the leeward flank at high altitude >1000 m, recorded the highest diversity, similar to studies on Mt. Uludag (Öztürk and Güvenç, 2010) with maximum diversities recorded at 1400 m and poor below 600 m. The highest lichen diversity and richness on Mt, Cameroon from the mid-high altitude (>500 m Lower Buea, Ekona Mbenge Bomana and Upper Buea) and lowest diversity at low altitude (<200 m IRAD Ekona, Batoke, Bakingili and Idenau) may be attributed to a number of factors influencing the abundance and richness of lichens such as altitude, humidity temperature, forest type and land use changes from human activities (Sevgi et al., 2019). Notably, Shyam et al. (2010) reported altitude as one of the main factor

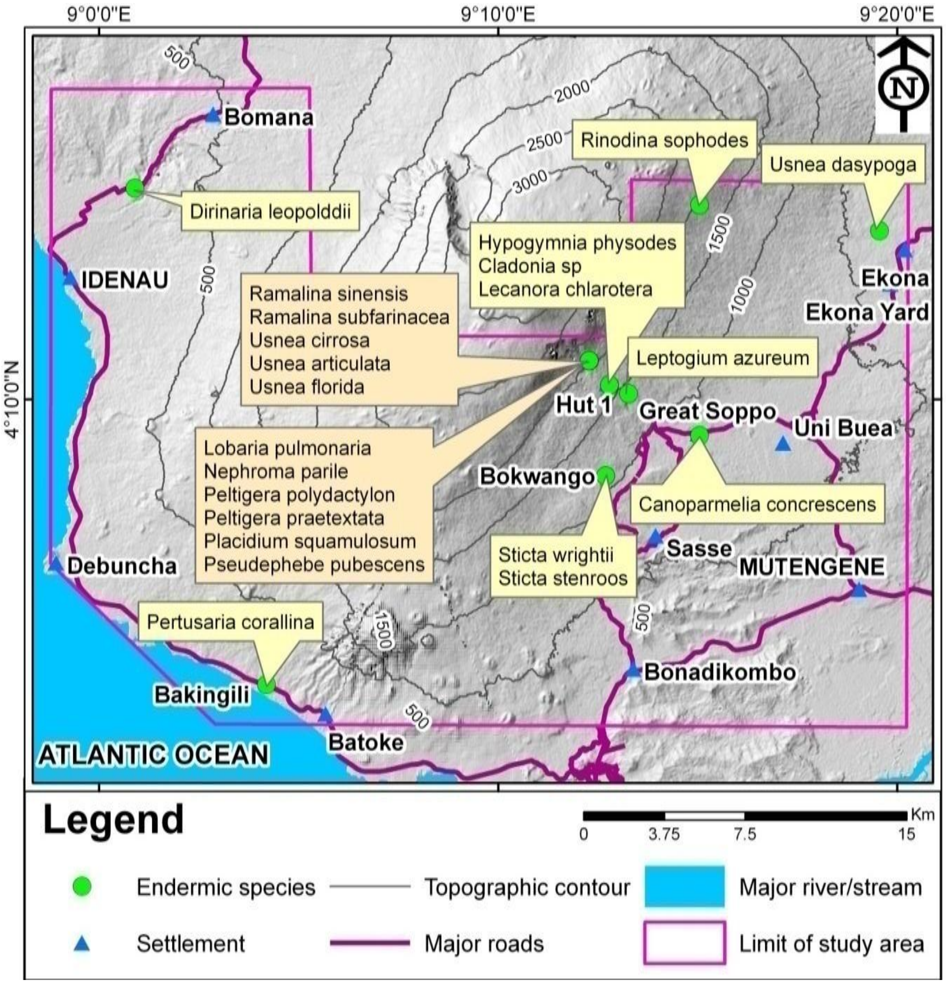

Figure 14. Identified site-specific lichen species and their collection points on Mt. Cameroon.

controlling the diversity and distribution of epiphytic lichens in Kollihills. Furthermore, Bassler et al. (2016) and Chitra et al. (2009), found decrease in lichen diversity along increasing altitude and their preference of corticolous habitat can be attributed to the abiotic factors such as humidity, light, temperature and substrate. All the sampling sites above 500 m in this study with high diversities, recorded higher humidity levels (>80 mm) than the sites below this elevation with lower humidity levels (<80 mm). Matteucci et al. (2012) in their studies observed that one of the most lichen-rich forest types with maximum species diversity and abundance are humid and cooler montane forest located in the cloud zones like the Upper Buea and Ekona Mbenge sampling sites. Most researchers (Nascimbene et al., 2010) have shown that, the composition of lichen communities depends on factors that operate at multiple spatial and temporal scales. At the local scale, lichen composition is mainly related to microclimatic and substrate factors associated with forest structure and continuity, while at broader scales climate and dispersal limitations are further important drivers.

The richness of species, growth forms and substrate types in this sites may be attributed to the well-developed preferences for habitats and microhabitats by lichens which are influenced by small differences in chemical (mineral contents) and physical factors (light, temperature, humidity, wind, altitude and unpolluted air, substrate) playing an important role in shaping lichen species richness patterns. A relationship between the concentration of certain lichen secondary compounds and the degree of exposure to environmental variables such as light, moisture, altitude, climate change and pollution have demonstrated (Brodo et al., 2001). A lichen's ability to protect itself from high levels of visible light and ultraviolet radiation is determined by the production of secondary compounds which influenced the habitats it is able to occupy (Hess et al., 2008;

Table 6. Checklist of lichen species in Cameroon as of 2012.

Family	Species	Feuerer's collection	Present study
Arthoniaceae	*Arthonia punctiformis*	-	+
	Herpothallon spp.	-	+
	Herpothallon rubrocinctum	-	+
Aspidotheliaceae	*Aspidothelium fugiens*	-	+
Catillariaceae	*Catillaria nigroclavata*	-	+
	Catillaria bouteillei	+	-
Chrysotrichaceae	*Chrysothrix candelaris*	-	+
	Chrysothrix chlorine	-	+
Cladoniaceae	*Cladonia convoluta*	-	+
	Cladonia spp.	-	+
	Cladonia diplotypa	+	-
	Cladonia fimbriata	+	-
Coccocarpiaceae	*Coccocarpia erythroxyli*	+	+
	Coccocarpia *pellita*	-	+
Coenogoniaceae	*Dimerella epiphylla*	+	-
Collemataceae	*Leptogium* aff.*azureum*	-	+
	Leptogium gelatinosum	-	+
	Leptogium burgessii	+	-
	Leptogium inflexum	+	-
	Collema nigrescens	+	-
Ectolechiaceae	*Lopadium fuscum*	+	-
	Lopadium phyllogenum	+	-
	Lopadium puiggarii	+	-
	Tapellaria epiphylla	+	-
	Tapellaria phyllophila	+	-
Gomphillaceae	*Aulaxina epiphylla*	+	-
	Aulaxina opegraphina	+	-
	Calenia depressa	+	-
	Calenia graphidea	+	-
	Echinoplaca epiphylla	+	-
	Echinoplaca pellicula	+	-
	Gyalectidium filicinum	+	-
	Tricharia albostrigosa	+	-
	Tricharia vainioi	+	-
Graphidaceae	*Graphis elegans*	-	+
	Graphis scripta	-	+
	Hemithecium rufopallidum	-	+
Lecanoraceae	*Bacidia inundata*	-	+

Table 6. Contd.

	Bacidia apiahica	+	-
	Bacidia pallidocarnea	+	–
	Bacidia rhapidophylli	+	–
	Bacidia stanhopeae	+	–
	Bacidia sublecanorina	+	-
	Lecanora cenisia	-	+
	Lecanora chlarotera	-	+
	Lecidella euphorea	-	+
	Lecidella elaeochroma f.elaeochroma	-	+
	Lecanora subfusca	+	-
Bacidiaceae	*Japewiella tavaresiana*	-	+
	Lobaria pulmonaria	-	+
	Lobaria quercizans	+	-
Lobariaceae	*Sticta fuliginosa*	+	-
	Sticta sp. Stenroos	-	+
	Sticta wrightii	-	+
Megalosporaceae	*Megalospora tuberculosa*	-	+
Megasporaceae	*Aspicilia calcarea*	-	+
Micareaceae	*Psilolechia lucida*	-	+
Monoblastiaceae	*Acrocordia conoidea*	-	+
Nephromataceae	*Nephroma parile*	-	+
Pannariaceae	*Microtheliopsis uleana*	+	-
	Arctoparmelia centrifuga	-	+
	Bulbothrix tabacina	-	+
	Bulbothrix meizospora	+	-
	Canoparmelia concrescens	-	+
	Flavoparmelia caperata	-	+
	Hypogymnia austeroides	-	+
	Hypogymnia physodes	-	+
	Hypotrachyna/(Parmelia) revoluta	+	+
	Parmelinella aff.Wallichiana	-	+
	Parmelia megaleia	+	-
	Parmeliella mariana	+	-
	Parmeliella stylophora	+	-
Parmeliaceae	*Parmotrema perlatum*	-	+
	Parmotrema stuppeum	-	+
	Parmotrema subrugatum	+	-
	Parmotrema tinctorum	-	+
	Pseudoparmelia sphaerospora	+	-
	Pseudephebe pubescens	-	+
	Punctelia subrudecta	-	+
	Remototrachyna spp.	-	+
	Tuckermannopsis platyphylla	-	+
	Usnea africana	+	-
	Usnea articulata	-	+
	Usnea baileyi	-	+

Table 6. Contd.

	Usnea bornmuelleri	+	-
	Usnea ceratina	+	-
	Usnea cirrosa	-	+
	Usnea dasypoga	-	+
	Usnea firmula	+	-
	Usnea florida	+	+
	Usnea hirta	-	+
	Usnea hispida	+	-
	Usnea implicata	+	-
	Usnea meyeri	+	-
	Usnea pulvinata	+	-
	Usnea pseudocyphellata	+	-
	Usnea submollis	+	-
	Xanthoparmelia plittii	-	+
Peltigeraceae	*Peltigera polydactylon*	+	+
	Peltigera praetextata	-	+
	Peltigera polydactyloides	+	-
	Peltigera rufescens	+	-
Pertusariaceae	*Pertusaria coralline*	-	+
Physciaceae	*Buellia frigida*	-	+
	Buellia stillingiana	-	+
	Buellia disciformis	-	+
	Dirinaria applanata	-	+
	Dirinaria aspera	-	+
	Dirinaria leopoldii	-	+
	Heterodermia boryi	-	+
	Heterodermia diademata	-	+
	Heterodermia flabellata	-	+
	Heterodermia japonica	-	+
	Heterodermia obscurata	-	+
	Heterodermia propagulifera	-	+
	Heterodermia squamulosa	-	+
	Heterodermia speciosa	+	-
	Physcia aipolia	-	+
	Physcia atrostriata	-	+
	Physcia biziana	-	+
	Physcia caesia	-	+
	Physcia dilatata	+	-
	Physcia speciosa var. *dactylifera*	+	-
	Physcia speciosa var. *hypoleuca*	+	-
	Pyxine berteriana	+	+
	Rinodina sophodes	-	+
Pilocarpaceae	*Byssolecania deplanata*	+	-
	Byssolecaniafumosonigricans	+	-
	Byssoloma leucoblepharum	+	-
	Byssoloma rotuliforme	+	-

Table 6. Contd.

	Sporopodium leprieurii	+	-
Porinaceae	*Porina heterospora*	-	+
	Porina epiphylla	+	-
	Porina epiphylla	+	-
	Porina follmanniana	+	-
	Porina imitatrix	+	-
	Porina limbulata	+	-
	Porina kamerunensis	+	-
	Porina mirabilis	+	-
	Porina nitidula	+	-
	Porina obducta	+	-
	Porina pallescens	+	-
	Porina radiata	+	-
	Porina semecarpi	+	-
	Porina sphaerocephala	+	-
	Porina tetramera	+	-
	Porina trichothelioides	+	-
	Trichothelium alboatrum	+	-
	Trichothelium annulatum	+	-
Pyrenulaceae	*Pyrenula* aff.*ochraceoflava*	-	+
	Melanotheca cameroonensis	+	-
Ramalinaceae	*Ramalina fastigiata*	-	+
	Ramalina sinensis	-	+
	Ramalina subfarinacea	-	+
	Ramalina scopulorum	+	-
Roccellaceae	*Cresponea permnea*	-	+
	Mazosia melanophthalma	+	-
	Mazosia paupercula	+	-
	Mazosia phyllosema	+	-
	Opegrapha puiggarii	+	-
Stereocaulaceae	*Lepraria ecorticata*	-	+
	Lepraria obtusatica	-	+
	Stereocaulon denudatum	+	-
	Stereocaulon turgescens	+	+
Strigulaceae	*Strigula elegans*	+	-
	Strigula elegans	+	-
	Strigula nemathora	+	-
	Strigula nitidula	+	-
	Strigula subtilissima	+	-
Teloschistaceae	*Caloplaca citrina*	-	+
	Caloplaca crenularia	-	+
	Caloplaca ferruginea	-	+
	Caloplaca fraudans	-	+

Table 6. Contd.

	Caloplaca microthallina	-	+
	Chroodiscus mirificus	+	-
	Diploschistes scruposus	+	+
Thelotremataceae	*Thelotrema cameroonensis*	+	-
	Thelotrema lepadinum	-	+
	Tremotylium africanum	+	-
Trypetheliaceae	*Asterothyrium pittieri*	+	-
Trapeliaceae	*Trapeliopsis flexuosa*	-	+
	Placidium squamulosum	-	+
Verrucariaceae	*Phylloblastia dolichospora*	+	-
	Phyllophiale alba	+	-

+ Present in a reference; -Abscent in a reference.

Paolo, 2019). Also, as lichens possess a wide range of optima with regards to light, moisture, temperature, substrate quality and stability, and nutrient inputs, various life-history traits (biomolecules accumulation from different photobiont in association) are expected to modify the lichen response to various environmental factor and land use (Aptroot and van Herk, 2007; Chuquimarca et al., 2019).

The abundant families (Physciaceae and Parmeliaceae) in this study correspond to the studies of Divakar et al. (2010), who found these as the most common families in tropical regions, particularly abundant in humid climates at mid-high elevations. The family Physciaceae with 17 species, harbours thermophilic lichens like H. obscurata and Physcia americana (Moberg, 2004) which response to distributional changes are attributed to global warming (Hickling et al., 2005) and are among the most common and particularly abundant in humid climates at low and mid elevations (Ellis and Coppins, 2017).

The most represented genus Usnea with 07 different species in tree canopies at high elevations is similar to study performed in West Greenland (Bjerke and Dahl, 2002) which showed that, lichen species with high concentrations of usnic acid inhabit more light-exposed areas than species with lower levels of this compound. Presumably, this may be the reason for the highest diversity and richness of canopy ramicolous fruticose and foliose usnic acid producing species at Upper Buea and Ekona Mbenge sampling sites. Most of these species and others were positive red and yellow with spot test than the species of the low altitude. This is findings are consistent with a survey of lichen distribution in Thailand by Wolseley and Aguirre-Hudson (1997) who found that, lichen which showed red and yellow colours with spot test were found at high-altitude montane oak forest and lacking in low-altitude tropical mixed deciduous forest. They reported that, lichen communities must experience a threshold level of light intensity before it becomes adaptive to begin producing expensive secondary compounds for protection from intense irradiance. This adaptation may be attributed to the absence of usnic acid producing species in the low altitude sampling sites of this work. Although these lower altitude sampling sites recorded higher mean light intensities (1706.9±5.6 lux) than high altitude (640.5±6.6 lux), the lichen species may not have experienced the threshold to produce irradiance-protecting substances because of land use changes.

At Mt. Cameroon, macro lichens (foliose, fruticose and squamulose) growth forms recorded highest diversities in the mid and high altitudes, while micro lichens (crustose, leprose and placodioid) growth forms were highest in the low altitude sites might have been influenced by land use activities. According to Ahti (2000), lichens show preferences to either sexual or asexual reproductive methods due to differences in morphological tolerance to trampling. For example, macro-lichens are more susceptible to trampling and so rarely reproduce sexually, while micro-lichens are more tolerant to trampling therefore reproduce both sexually and asexually. Therefore, foliose growth forms with the most representative probably relates to the fact that the presence of foliose lichens is independent of landscape condition and relies on a small amount of fragmentation to disperse to new sites (Cáceres et al., 2007). Managed forests like those in the low altitude (Batoke, Bakingili, Idenau and Ekona IRAD) are normally young and fragmented for wood fuel, timber and plantation agriculture in which young tree stems are repeatedly cut down to near ground level with short rotation cycles (Kaufmann et al., 2017). Management activities such as forestry (Aragon et al., 2010) agriculture (Styres et al., 2010) livestock grazing and quarrying (Boudreault et al., 2008) have been recognized as the most important driving forces for lichen species richness and composition. Habitat fragmentation (Kubiak et al., 2016) has led to the isolation of many lichen communities by creating limitations and hampering their dispersal and reproduction (Lorenzo et al., 2011). The generation time, from spore to spore determined in some lichens takes so many years (Ranius et al., 2008). Red-list species *Cliostomum corrugatum* and *Lobaria pulmonaria* for example, have reach an average age of 30 and 35 years respectively before they are able to produce and disperse their spores (Edman et al., 2008).

Mature forests like Upper Buea sampling site with high conservation value are forest where regeneration is usually of seedling origin, either natural or artificial (or a combination of both) and the rotation cycles are generally long to harbour red-list threaten species (Hofmeister et al., 2015). Owing to the evidence of their low dispersal ability and long generation the red-list has been widely used as an indicator species of undisturbed forest ecosystems and forest areas of a high ecological continuity and conservation (Nascimbene et al., 2014; Vondrak et al., 2015). This dispersal limitation may be one of the reasons for more (17) site-specific species including *L. pulmonaria* at Upper Buea in the high. Furthermore, the IUCN (2000) red-list criteria emphasizes the conservation of lichen species in areas were rating is not abundant, like case with Mt. Cameroon where rating is mostly common (31%).

Most lichens occurring in Mt. Cameroon are corticolous (tree) species with the highest diversity of perennial substrates in Upper Buea sampling site. Ioana (2011) revealed some lichens, especially the endangered red-listed species are restricted to specific perennial substrates and habitats in montane regions. The vegetation in Upper Buea still covers relatively large and continuous areas with perennial substrates for colonisation and stability of the genera *Lobaria, Nephroma*, *Ramalina, Cladonia* and *Usea*. These red-list species are found on branches and twigs with dense canopies of mature trees with rough barks. According to Ellis and Coppins (2007), these lichens have some degree of substrate specificity and stability of the habitats over a long period giving an impact of lichen status. Therefore, the probable reason for the high diversity of quality perennial substrates in Upper Buea site may be attributed to forest maturity and reduced human activity unlike IRAD Ekona, Batoke, and Idenau which are highly disturbed by land use changes from anthropogenic activities like agriculture. Since many species are restricted to specific microclimatic pockets, any change in the original structure of the forest will decrease species diversity (Benıtez et al., 2018).

Deforestation of old forest for instance leads to the removal of decaying logs and stumps and conversion to secondary forest with different substrate quality in the low altitude resulting in a decrease in species diversity like the case of this study. Pinho et al. (2008) reported that the nature of the substrate (tree age, size and bark nature, that is, rough or smooth) has considerable influence on the diversity and abundance of lichen species. This may be reflected by smooth bark *Graphis scripta, Arthonia punctiformis, Lecidella elaeochroma* species for example, recorded in the young tree with smooth barks found in the lower altitude sampling sites.

The Mt. Cameroon windward flank (Batoke, Bakingili, Idenau and Bomana) of this study, recorded fewer lichen species than the leeward flank (Upper and lower Buea, IRAD and Ekona Mbenge) which can be attributed to air quality. Bjerke (2011) reported that wind often favours lichen growth, distribution and abundance positively if the wind circulation is nutrient-rich or negatively if the wind circulation is pollutant-rich (Paolo, 2019). This may be the effect of the poor lichen diversity and richness in the windward flank because, studies by Suh et al. (2008) reveal the dominant prevailing winds direction of Mt. Cameroon is from the NE-SW direction, which tends to drive volcanic ash plumes and degassing over the south-western (windward) flank. Upper Buea sampling site situated in the leeward flank recorded all the fruticose air quality sensitive species and none of this species was recorded in any of the sampling sites in the windward flank. Perlmutter (2010) recognised air quality as one of the main factors influencing development of lichen species. They found that shrubby lichens (fruticose) thrive in clean air while only crusty lichen thrives in polluted air. Using the Rose and Harkworth (1970) scale documented in Brodo et al. (2001), the assemblage of lichen species in Upper Buea in the high altitude has the best air quality. This was indicated by the occurrence of all the fruticose and foliose lichen species in the genera (*Lobaria, Nephroma*, *Ramalina, Cladonia, Usea* and *Flavoparmelia*) associated with good air quality.

Feuerer (2011), listed only 101 lichenized fungal for the Republic of Cameroon, but according to these findings, out of the 89 lichen species identified, 82 species were not found on Feuerer list, therefore are added as new species records for Cameroon lichen check list. According to Feuerer and Hawksworth (2007), the lichen mycobiota in most regions, especially in the tropics, is still largely unknown and surveys will always reveal new species. The numerous new species in Cameroon indicates that Mt. Cameroon lichens are still unexplored, and new inventories are required to understand the potential of its diversity. This research generates new data on lichen of MC and contributes to a better understanding of the existing lichen flora.

Conclusion

Despite harbouring rich lichen diversity, the Mt. Cameroon region in particular and Cameroon in general is grossly under explored. Mt Cameroon has a thick moist forest vegetation which provide a suitable habitat for the colonization of different lichen species on different substrates. The high altitudes and the Leeward sites show less anthropogenic pressure and less habitat alteration. It is no surprise that the habitats with the highest lichen species diversity are the remnants of ancient forests and undisturbed ecosystems like Upper Buea sampling site.

Current study reveals region-specific distribution of lichens, which is very different in the sampling sites of Mt. Cameroon region. This disparity can be primarily attributed to the different climatic factors and anthropogenic pressures in the form of land use patterns influencing the lichen communities of the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix 1. Diversity of lichens in Mt Cameroon.

Species	Family	Order	Substrate	Growth form	Sites 1	2	3	4	5	6	7	8
Acrocordia conoidea (Fr.) Körb	Monoblastiaceae	Pyrenulales	Wood	C	-	-	+	+	+	-	-	-
Arctoparmelia centrifuga (L.)Hale.	Parmeliaceae	Lecanorales	Rock	Fo	-	-	+	+	-	-	-	+
Arthonia punctiformis Ach.	Arthoniaceae	Arthoniales	Tree	C	-	+	+	-	-	-	-	-
Arthoprenia nitescen (Salwey) Mudd	Arthopyreniaceae	Incertae sedis	Tree	C	-	-	+	-	-	-	-	-
Aspicilia calcarea (L.)Mudd,Man.	Megasporaceae	Pertusariales	Rock	C	+	-	+	-	-	+	-	-
Bacidia inundata (Fr.) Körb	Ramalinaceae	Lecanorales	Tree	C	-	-	-	+	+	+	+	+
Buellia disciformis (Fr.)Mudd Man.	Physciaceae	Lecanorales	Wood	C	+	-	+	-	-	-	-	+
Buellia frigida Darb	Physciaceae	Lecanorales	Tree	C	+	+	+	+	+	+	-	+
Buellia stillingiana J.Steiner	Physciaceae	Lecanorales	Tree	C	+	+	+	+	+	+	-	+
Bulbothrix tabacina (Mont. & Bosch) Hale	Parmeliaceae	Lecanorales	Tree	Fo	+	+	+	+	-	-	-	-
Caloplaca citrine (Hoffm.)Th.Fr.	Teloschistaceae	Teloschistales	Tree/wall	C	+	+	+	+	+	+	-	-
Caloplaca crenularia (With.) J.R. Laundon	Teloschistaceae	Teloschistales	Tree	C	-	+	-	-	-	-	-	-
Caloplaca ferruginea (Huds.) Th. Fr.	Teloschistaceae	Teloschistales	Wood	C	-	-	+	+	-	-	-	-
Caloplaca fraudans (Th.Fr.)H.Olivier	Teloschistaceae	Teloschistales	Tree	C	-	-	-	+	-	-	-	-
Caloplaca ignea Arup	Teloschistaceae	Teloschistales	Rock	C	+	-	+	+	+	+	-	-
Caloplaca microthallina (Wedd.) Zahlbr.	Teloschistaceae	Teloschistales	Wood	C	-	-	-	-	+	-	-	-
Canoparmelia concrescens (Vain.) Elix & Hale	Parmeliaceae	Lecanorales	Tree	Fo	-	-	+	-	-	-	-	-
Chrysothrix candelaris (L)J.R.Laundon	Chrysotrichaceae	Arthoniales	Tree	Lep	+	+	+	+	+	+	+	+
Chrysothrix chlorina (Ach.) J.R.Laundon	Chrysotrichaceae	Arthoniales	Tree/wood/rock	Lep	+	+	+	+	+	+	+	+
*Cladonia convoluta (*L.) Hoffm. Duke	Cladoniaceae	Lecanorales	Lava	Dim	-	+	-	+	-	+	-	-
Cladonia sp	Cladoniaceae	Lecanorales	Rock	Fr	-	-	-	+	-	-	-	-
Coccocarpia erythroxyli Pers	Coccocarpiaceae	Peltigerales	Mossy tree	Squ	-	-	-	+	-	-	-	+
Coccocarpia pellita (Ach.) Müll. Arg.	Coccocarpiaceae	Peltigerales	Lava	Squ	-	+	-	+	-	-	-	-
Cocotrema maritimum Müll Arg.	Cocotremataceae	Pertusariales	Lava	Lep	-	+	-	+	-	+	-	-
Cresponea permnea (Nyl.)Egea &Torrente.	Roccellaceae	Arthoniales	Tree	C	-	-	+	-	-	-	-	-
Dirinaria applanata (Fee)D.D.Awasthi	Physciaceae	Lecanorales	Tree/rock	Pla	+	+	+	+	+	+	+	+
Dirinaria aspera (H. Magn.) D.D. Awasthi	Physciaceae	Lecanorales	Tree	Pla	-	-	+	-	-	-	-	-
Dirinaria leopoldii (Stein) D.D. Awasthi	Physciaceae	Lecanorales	Mossy tree	Pla	-	-	-	-	-	-	+	-
Flavoparmelia caperata (L)Hale.	Parmeliaceae	Lecanorales	Tree/rock	Fo	+	+	+	+	-	-	-	-
Graphis elegans (Borrer ex Sm.) Ach.	Graphidaceae	Ostropales	Tree	C	-	-	+	-	-	-	-	-
Graphis scripta (L.)Ach	Graphidaceae	Ostropales	Tree	C	-	-	+	-	-	-	-	-
Graphis sp	Graphidaceae	Ostropales	Tree	C	+	+	+	-	+	+	-	+
Herpothallon rubrocinctum (Ehrenb.: Fr.) Aptroot, Lücking & G. Thor	Arthoniaceae	Arthoniales	Wood	C	-	-	+	+	+	+	+	+

Appendix 1. Contd.

Herpothallon sp	Arthoniaceae	Arthoniales	Wood	C	-	-	+	+	+	-	-	+
Heterodermia boryi (Fée) K.P. Singh & S.R. Singh	Physciaceae	Lecanorales	Twig	Fo	-	-	-	+	-	-	-	-
Heterodermia diademata (Taylor.)D.D.Awasthi.	Physciaceae	Lecanorales	Twig	Fo	-	-	+	+	-	-	-	-
Heterodermia flabellata (Fee.)D.D.Awasthi.	Physciaceae	Lecanorales	Tree	Fo	-	-	+	+	-	-	-	-
Heterodermia japonica (Sato)Swinscow&Krog	Physciaceae	Lecanorales	Mossy tree/rock	Fo	+	-	+	+	-	+	-	+
Heterodermia obscurata (Nyl.)Trevis, Nuovo Giorn.	Physciaceae	Lecanorales	Tree/rock	Fo	+	+	+	+	-	-	-	+
Heterodermia propagulifera (Vain.)J.P. Dey.	Physciaceae	Lecanorales	Mossy tree	Fo	-	-	-	+	-	-	-	-
Heterodermia squamulosa (Degel.)Culb.	Physciaceae	Lecanorales	Tree/rock	Fo	-	-	+	-	-	-	-	-
Hypogymnia austeroides (Nyl.)Nyl	Parmeliaceae	Lecanorales	Tree	Fo	-	-	+	-	-	-	-	-
Hypogymnia physodes (L.)Nyl	Parmeliaceae	Lecanorales	Tree	Fo	-	-	-	+	-	-	-	-
Hypotrachyna afrorevoluta (Flörke) Hale	Parmeliaceae	Lecanorales	Tree	Fo	-	-	+	-	-	-	-	-
Japewiella tavaresiana (H. Magn.) Printzen	Bacidiaceae	Lecanorales	Twig	C	-	+	-	+	-	-	-	-
Lecanora cenisia Ach.	Lecanoraceae	Lecanorales	Tree	C	-	+	-	+	-	-	-	-
Lecanora chlarotera Nyl	Lecanoraceae	Lecanorales	Twig	C	-	-	-	+	-	-	-	-
Lecidella elaeochroma f. elaeochroma (Ach.) M.Choisy Seaward & Hitch	Lecanoraceae	Lecanorales	Tree	C	-	-	-	+	-	-	-	-
Lecidella euphoria (Florke)Hertel.	Lecanoraceae	Lecanorales	Wood	C	+	-	-	-	-	-	-	-
Lepraria ecorticata (J.R. Laundon) Kukwa	Stereocaulaceae	Lecanorales	Rock	Lep	-	+	+	+	+	+	+	+
Lepraria obtusatica Tønsberg	Stereocaulaceae	Lecanorales	Tree/rock	Lep	-	-	-	+	-	-	-	-
Leptogium azureum (Sw.) Mont	Collemataceae	Peltigerales	Mossy tree	Fo	-	-	-	+	-	-	-	-
Leptogium gelatinosum (With.) J.R. Laundon	Collemataceae	Peltigerales	Mossy tree/rock	Fo	+	+	+	+	+	+	+	+
Lobaria pulmonaria (L.)Hoffm	Lobariaceae	Peltigerales	Tree	Fo	-	-	-	+	-	-	-	-
Megalospora tuberculosa (Fée) Sipman	Megalosporaceae	Pertusariales	Tree	C	-	-	+	+	-	-	-	+
Nephroma parile (Ach.)Ach.	Nephromataceae	Peltigerales	Tree	Squ	-	-	-	+	-	-	-	-
Parmelinella aff. Wallichiana(Taylor)Elix&Hale	Parmeliaceae	Lecanorales	Tree/rock	Fo	+	+	+	+	-	-	-	-
Parmotrema perlatum (Huds.) M.Choisy	Parmeliaceae	Lecanorales	Tree/rock	Fo	+	+	+	+	-	-	-	-
Parmotrema stuppeum (Taylor)Hale	Parmeliaceae	Lecanorales	Tree/rock	Fo	+	+	+	+	-	-	-	-
Parmotrema tinctorum (Despr.ex NYL.)Hale	Parmeliaceae	Lecanorales	Tree/rock	Fo	+	+	+	+	-	-	-	-
Peltigera praetextata (Flörke ex Sommerf.) Zopf	Peltigeraceae	Lecanorales	Tree	Fo	-	-	-	+	-	-	-	-
Peltigera polydactylon (Neck.) Hoffm.	Peltigeraceae	Lecanorales	Tree	Fo	-	-	-	+	-	-	-	-
Pertusaria corallina (L.) Arnold	Pertusariaceae	Pertusariales	Rock	C	-	-	-	-	-	+	-	-
Physcia aipolia (Mont. & Bosch) Hale	Physciaceae	Lecanorales	Twig	Fo	-	-	+	+	-	-	-	-
Physcia atrostriata Moberg	Physciaceae	Lecanorales	Tree	Fo	-	+	+	-	+	-	-	+
Physcia biziana. (Massal.)Zahlbr	Physciaceae	Lecanorales	Wood	Fo	-	+	-	+	-	-	-	-
Physcia caesia (Hoffm.) Furnr.	Physciaceae	Lecanorales	Tree/Rock	Fo	+	+	+	-	-	-	-	-
Placidium squamulosum(Ach.) Breuss	Verrucariaceae	Verrucariales	Tree	Squ	-	-	-	+	-	-	-	-
Porina heterospora (Fink *ex* J. Hedrick) R.C. Harris	Porinaceae	Trichotheliales	Tree	C	+	+	+	+	+	+	+	+

Appendix 1. Contd.

Pseudephebe pubescens (L.) Choisy	Parmeliaceae	Lecanorales	Twig	Fr	-	-	-	+	-	-	-	-
Psilolechia lucida (Ach.) M.Choisy	Micareaceae	Lecanorales	Tree/rock/soil	Lep	-	-	+	+	+	-	-	-
Punctelia subrudecta (Nyl)Krog	Parmeliaceae	Lecanorales	Tree/rock	Fo	+	-	+	+	-	-	-	-
Pyrenula aff.ochraceoflava (Nyl.)R.C.Harris	Pyrenulaceae	Pyrenulales	Tree	C	-	+	-	-	-	-	+	-
Ramalina fastigiata (Pers.) Ach.	Ramalinaceae	Lecanorales	Twig	Fr	-	+	-	+	-	-	-	-
Ramalina sinensis Jatta	Ramalinaceae	Lecanorales	Twig	Fr	-	-	-	+	-	-	-	-
Ramalina subfarinacea (Nyl. *ex* Cromb.) Nyl.	Ramalinaceae	Lecanorales	Twig	Fr	-	-	-	+	-	-	-	-
Remototrachyna sp	Parmeliaceae	Lecanorales	Rock	Fo	-	-	+	-	-	-	-	-
Rinodina sophodes (Ach.) A.Massal.	Physciaceae	Lecanorales	Rock	C	-	+	-	-	-	-	-	-
Sticta sp. Stenroos	Lobariaceae	Peltigerales	Wood	Fo	-	-	-	+	-	-	-	-
Sticta wrightii Tuck.	Lobariaceae	Peltigerales	Tree	Fo	-	-	-	+	-	-	-	-
Trapeliopsis flexuosa (Fr.) Coppins & P.James	Agyriaceae	Agyriales	Wood	C	-	-	+	-	+	+	+	+
Thelotrema lepadinum (Ach.)Ach.	Thelotremataceae	Ostropales	Tree	C	+	+	+	+	+	+	+	+
Tuckermannopsis platyphylla (Tuck.)Hale.	Parmeliaceae	Lecanorales	Wood	Fo	-	-	+	+	-	-	-	-
Umbilicaria spodochroa (Nyl.)Harm	Umblicaraceae	Lecanorales	Tree	Fo	-	-	-	+	-	-	-	-
Usnea cirrosa Mot.	Parmeliaceae	Lecanorales	Twig	Fr	-	-	-	+	-	-	-	-
Usnea articulate(L.)Hoffm	Parmeliaceae	Lecanorales	Twig	Fr	-	-	-	+	-	-	-	-
Usnea baileyi Stirt	Parmeliaceae	Lecanorales	Tree/rock	Fr	-	+	+	+	-	-	-	-
*Usnea florida (*L.) Wigg	Parmeliaceae	Lecanorales	Twig	Fr	-	-	-	+	-	-	-	-
Usnea dasypoga (Ach.) Nyl.	Parmeliaceae	Lecanorales	Tree	Fr	-	+	-	-	-	-	-	-
Usnea hirta (L.)F.H.Wigg.	Parmeliaceae	Lecanorales	Tree	Fr	-	-	-	+	-	-	-	-
Xanthoparmelia hottentota aff.epacridea Maf-Lich	Parmeliaceae	Lecanorales	Rock	Fo	-	+	+	-	-	-	-	-

+: Species present in the site. - : Species absent in the site. Sites: 1 IRAD Ekona (419m) 2. Ekona Mbegue (406 – 790 m); 3. Lower Buea (581 - 985 m); 4. Upper Buea (1108 - 2178 m); 5. Batoke (9 - 320 m); 6. Bakinglili (9 - 425 m); 7. Idenau (3 - 260 m); 8. Bomana (276 - 596 m).

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Review of the status of African lion (*Panthera leo*) in Ethiopia

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African lion (*Panthera leo*), is an important species in the Ethiopian ecosystems. However, significant lion populations and their suitable habitats in many of their former ranges in Ethiopia have declined over time due to socioeconomic uncertainty and the resulting ecological imbalances. Despite this general trend, it is equally noted that there is a lack of verifiable data which depicts the past and current status of African lions. Thus, very little is known about the species in question in most of its ranges. Available published and unpublished reports and manuscripts on the target species were reviewed in order to examine and document the status of the African lion in Ethiopia. From our review, we concluded that the lion numbers are still low and declining whilst considerable ranges have been identified through the field assessments conducted in the last two decades. African lions in Ethiopia have been under serious threat from various anthropogenic activities and it is therefore recommended to effectively implement the national conservation action plan for lion and undertake further field assessment on its habitats. This study suggests the establishment of a national Red list category for the threatened species based on the final reports of our assessments.

Key words: Trends, abundance, distribution, threats, conservation.

INTRODUCTION

The populations of African lion (*Panthera leo*, Linnaeus, 1758), which are key stone species in a given ecosystem require large tracts of undisturbed land with ample prey, permanent water and sufficient cover for raising their cubs. Since they inhabit areas where a relatively large natural habitat and herds of prey population occur, lions are usually considered indicators of a stable ecosystem and self-sustaining community of larger grazers (Nowell and Jackson, 1996; Kingdon, 1997; Yirga et al., 2017).

Ethiopia is believed to play an important role in the African lions' distribution pattern as they were distributed throughout most of its areas. Lions have been an important element in the Ethiopian ecosystems that range from evergreen montane forests to open savannah grassland, to semi-arid and arid lowland areas (Gebretensae et al., 2007; Gebresenbet et al., 2009; Riggio et al., 2013; Yirga et al., 2017). However, the ever-increasing human population, economic uncertainty, social and cultural disruption and the resulting ecological imbalance have adversely affected the wildlands of the country and even the formerly established protected areas are under increased anthropogenic pressure

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(Gebretensae et al., 2007; Gebresenbet et al., 2009; Yirga et al*.,* 2017). As a result, significant lion populations and their suitable habitats in many of their former ranges in Ethiopia have declined over time (Bauer et al., 2016; Kebede and Gebretensae, 2018; Yirga et al., 2021).

Despite this fact, it is equally important to note that there is a lack of reliable and justifiable data as well as up-to-date information which depict the past and current status of lions and other carnivores for various reasons. From the perspective of Ethiopia, very little is known about larger carnivores in most of their ranges including the designated protected areas. In areas where there is little information, long-term population data are not available and most of the information gathered so far has been dependent on guess works (Riggio et al., 2013; Kebede and Gebretensae, 2018).

Therefore, this review aims at examining and documenting the past and present status of distribution, population and conservation of African lions in Ethiopia based on the available reports and relatively reliable information.

Taxonomic status of African lion in Ethiopia

Even though all African lion (*P. leo,* Linnaeus, 1758) is currently considered monotypic (Kingdon, 1997; Bauer et al., 2013), the genetic status of their population is still unknown and needs to be examined. Some studies explain that there are phenotypically and genetically distinct African lions. For example, Bruche et al. (2013) reported that the Addis Ababa Zoo lions are distinct from Asian lions as well as all African lion populations for which comparative data were available. However, recent finding that based on the genetic analysis of samples collected from various parts of Ethiopia shows that the existing lions are admixture of the northern and southern subspecies and it has been hypothesized that the existing patterns have arisen as a result of a naturally occurring hybridization zones (Bertola et al., 2019).

METHODS

Study area

This review was conducted to examine the status distribution, population and conservation of African lions in Ethiopia. Ethiopia's relatively vast land area of some 1.12 million km^2, boasts huge variation in topography and climate. Indeed her lands soar from the heights of 4543 m *asl* on the peak Ras Dajen down to the hot baking plains of the Danakil depression, some 116 m below sea level. In between Ethiopia's Great Plains sit atop two massive highland plateaus cloven by the Great Rift Valley. These highland plateaux, cut by deep gorges and 12 major river valleys, dominate much of the interior of Ethiopia. The differences in altitude, topography and distance from the ocean cause massive variation in rainfall, humidity and temperature and have created the ten ecosystem types of Ethiopia, from cool afro-alpine to evergreen montane forests, to dry desert scrubland. Ethiopia is consequently endowed with a diverse suite of biological resources and the isolation of its mountain and desert areas has given rise to numerous endemic species of flora and fauna found nowhere else on Earth (Biodiversity Indicators Development National Task Force, 2010). To support the conservation of this rich wildlife resource, over 77 Protected Areas (PAs) of different categories have been created over the last six decades (EWCA, 2020; IUCN ESARO, 2020).

Literature sources

This status review is based on survey of various scholarly sources, published and unpublished reports and conservation strategy documents related to the target species. The National Action Plan for the conservation of the African Lion in Ethiopia (Gebresenbet et al., 2009; EWCA, 2012) and the corporate plans of wildlife sector (EWCA, 2020) are the strategy documents that were considered to undertake this review. Google's search engine, Google Scholar (http://scholar.google.com) and Science Direct (https://www.sciencedirect.com) were used to get the review materials that are not found in local libraries and archives.

For the review, a total of 29 articles and books published in the past 25 years have been reviewed. Besides, 15 unpublished reports of assessment on wildlife resources and human-wildlife conflict, which were submitted since 2007 to different departments of the Ethiopian Wildlife Conservation Authority (EWCA) were used for the review.

In order to assess the habitats of the extant populations of lions, various census reports on wild fauna (Ewnetu et al., 2010; Yadeta and Hailu, 2013; Wendim et al., 2015; Yadeta and Getachew, 2016; Kebede et al., 2017; Wendim, 2018) and assessment reports on human-wildlife conflict (Gebretensae et al., 2007, 2008; Wendim and Yadeta, 2013; Siege et al., 2016; Assefa and Teklu, 2017; Zerfu et al., 2019) were used as key sources and these were supplemented by direct field observation, publications, previous reports of IUCN SSC Cat Specialist Group (Bauer et al., 2016; IUCN SSC Cat Specialist Group, 2018) and other documents related to conservation of African lion.

According to most census reports, line transects were used for sample counts and the wild animals were counted along randomly placed line transects where counting was done between 200 and 300 m width in either side of each transect based on the sampling protocol adopted by Norton-Griffiths (1978), Sutherland (1996) and Wilson et al. (1996).

However, most of the populations are believed to be overestimated since the methods depend on simplistic approaches of extrapolations that rely on suitable habitats without taking into consideration the prey-predator relationships and other key ecological aspects. For this reason, most of the results from the field surveys were not considered to determine population estimate but they were vital in defining the distribution of the lions. Therefore, in most cases extrapolations derived from conservative assumptions were used to estimate the populations of the species in question. The assumptions were the lion densities in most ranges are likely to be low since prey densities are low. In this regard, it is conservatively assumed a density of 1 to 2 lions/100 km^2 as adopted by Bauer and Van Der Merwe (2004).

The maps and Global Positioning System (GPS) readings indicated in the published and unpublished reports were used to determine the distributions of African lions and their potential threats.

Review of experts' opinion

In 2006, the IUCN organized a lion conservation workshop for wildlife authorities from all lion range countries within Eastern and Southern Africa (IUCN, 2006). The workshop consisted of a

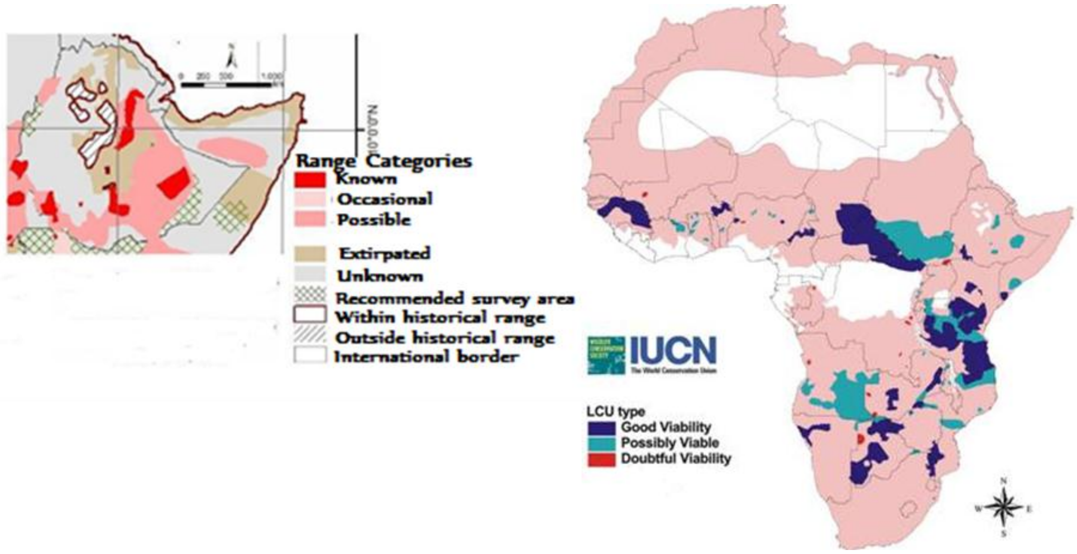

Figure 1. Range of African Lion (2006) (R) and African Lion Distribution and Population Viability (LCU-Lion Conservation Unit) (L).
Sources: IUCN Lion Conservation Strategy (2006).

technical session to map current lion range and status, followed by a strategic planning session to develop lion conservation strategies. The technical session was modeled after the range wide priority setting process developed by WCS for jaguars (Sanderson et al., 2002). Accordingly, experts were guided to produce maps of current lion range and delimit areas harboring known or suspected populations called Lion Conservation Units (LCUs) (IUCN, 2006). LCU delimitation relied on evidence of lion presence within the preceding 10 years and for each LCU participants assigned lion population trends and approximate lion population size. Although the data presented at the 2006 workshop date from 1990s onwards, it was the first expert-based comprehensive dataset on lion distribution in Eastern and Southern Africa and this was used as baseline for this review.

RESULTS AND DISCUSSION

Trend in distribution of African lion in Ethiopia

Even though it is generally believed that Ethiopia plays an important role in the African lion distribution pattern (Kebede and Gebretensae, 2018), it is true that it has been difficult to get up-to-date and reliable data on large carnivores. As a result, there is limited information on the distribution of large carnivores in Ethiopia and most of the information gathered so far has been dependent on assumptions and unverifiable sources (Riggio et al., 2013). For instance, there was a considerable concern about the consistency of the information on which the LCU had based to find out the then existing and former ranges of African lion in 2006 (Figure 1).

As pointed out earlier, efforts were made to assess the status of African lion in its possible ranges in order to update the distribution of this flagship species. During the workshop held in Addis Ababa, in 2009 to develop National Action Plan for conservation of the lion in Ethiopia, some additional information about the then status of lion was obtained and based on this the following map was produced (Figure 2).

The recent published extrapolations indicate that the major lion populations that are found within Ethiopia include Boma-Gambella, South Omo, Welmel-Genale, Ogaden, Awash basin, Bale and Nechisar areas, the largest-Boma Gambella, being shared with areas in South Sudan (Riggio et al., 2013). The IUCN Red list assessment (Bauer et al., 2016) updated the former ranges and extrapolated the locations for extant and possibly extinct populations in Ethiopia in which additional ranges in the north western part, specifically, Alitash areas were considered.

As part of implementation of the National Action Plan, field assessments of possible lion range habitats have been undertaken and reports of the assessments of wildlife potential areas in various parts of the country reveal that many areas indicated as possible extinct ranges on the updated map indicated in Bauer et al. (2016) are still the locations for considerable populations of lion.

Accordingly, reports on assessments conducted since 2007 indicate that there are considerable populations of lion at Gara-Gumbi Open Hunting Area which also further extends to Chercher/Arsi-Hararge massifs (Gebretensae et al., 2008). The human-lion conflict incidences around Hadiya zone show that there is remnant population of African lion which occasionally moves to the upper part of Gibe Valley (Gebretensae et al., 2007). Recent reports also depict that considerable populations are present in

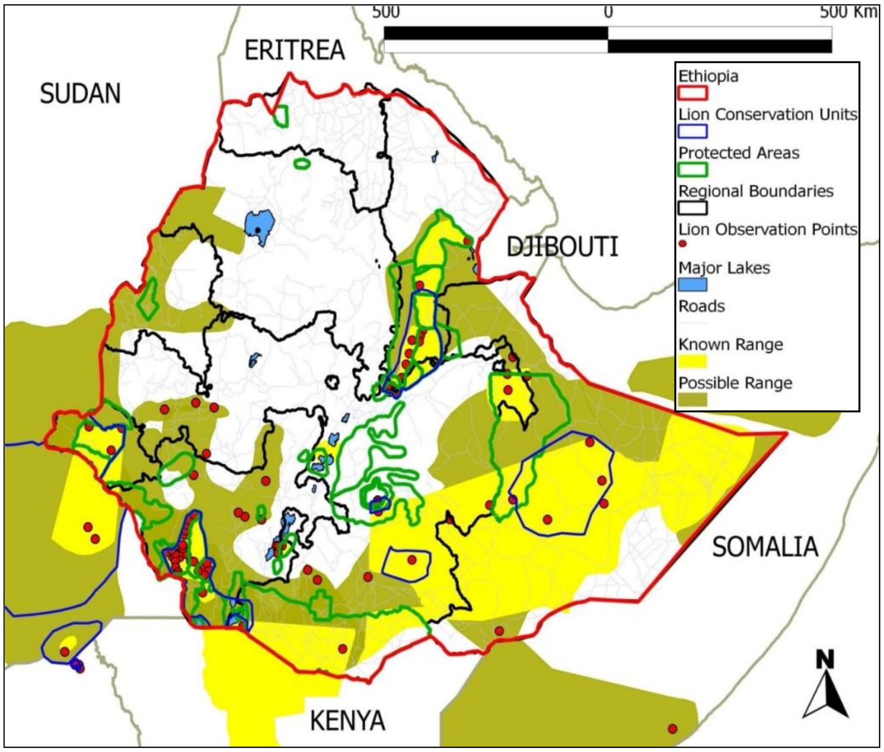

Figure 2. African lion distribution map produced based on information obtained from the national workshop participants (2009).
Some of the Regional and PA boundaries may not be placed properly.

the Shebelle-Genale-Dawa (Afder, Liben and Dawa zones) and Dabus-Mao-Komo-Begimiz areas in the southern and western part of the country, respectively (Yadeta and Hailu, 2013; Wendim et al., 2015; Yadeta and Getachew, 2016; Wendim, 2018; Bauer et al., 2019). The report of the rapid assessment in the north western part of Ethiopia, which was supported by camera traps confirms that a trans-boundary population of African lion exists in Alitash National Park of Ethiopia and Dinder National Park and Biosphere Reserve of Sudan (Bauer and Rksay, 2016; Bauer et al., 2017) and this finding reveals also that Sudan is one of the Range States for Africa lion. Yabello (Borena) National park and Chelbi Wildlife Reserve of the extreme southern areas as well as Nechisar and Maze National Parks in the middle south are also the present locations for some populations of the species in question (Pers. Comm).

Therefore, based on the up-to-date information obtained so far, substantial amount of areas in the north-western, western and southern part of Ethiopia are considered as present ranges for African lion (Figures 3 and 4).

Trend in abundance of African lion in Ethiopia

As explained earlier, endeavors have been made by experts in the field to collect a relatively reliable data and associated information on African lions over the last decade so as to depend on a relatively justifiable approach and gather reliable information on lion population that reflect the current situation on the ground thereby establish database which in turn can be used as inputs in devising sound lion conservation mechanisms. Riggio et al. (2013), which is one of the recent published reports indicates that seven lion populations exist within Ethiopia as indicated in Table 1.

Following this, various field assessments were conducted and these surveys have clearly indicated that there are still more populations of African lion. Recent reports depict that some populations are present in Shebelle-Genale-Dawa (Afder, Liben and Dawa zones) and Dabus-Mao-Komo-Begimiz areas in the southern and western part of the country, respectively (Yadeta and Hailu, 2013; Wendim et al., 2015; Yadeta and Getachew, 2016; Wendim, 2018; Bauer et al., 2019). The report of the rapid assessment in the north western part of Ethiopia, which was supported by trapping cameras conforms that a transboundary population of African lion exists in Alitash National Park of Ethiopia and Dinder National Park and Biosphere Reserve of Sudan (Bauer and Rskay, 2016; Bauer et al., 2017).

Therefore, the population assessments mentioned earlier conform that there are additional LCUs that may

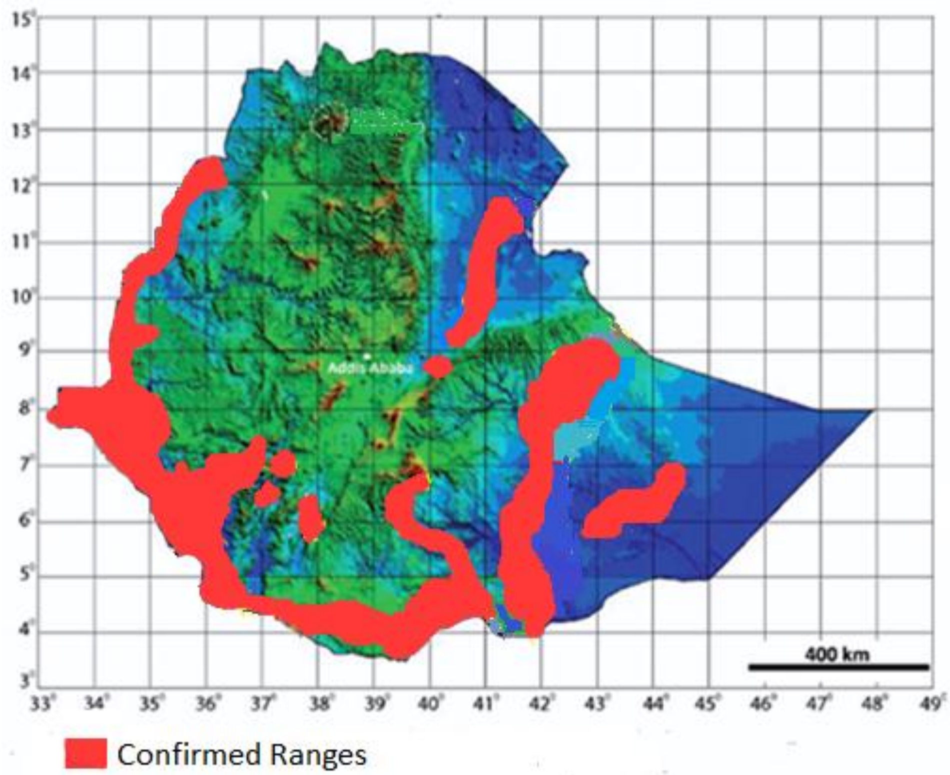

Figure 3. Present confirmed distribution of Africa lion in Ethiopia (based on the result of this review).

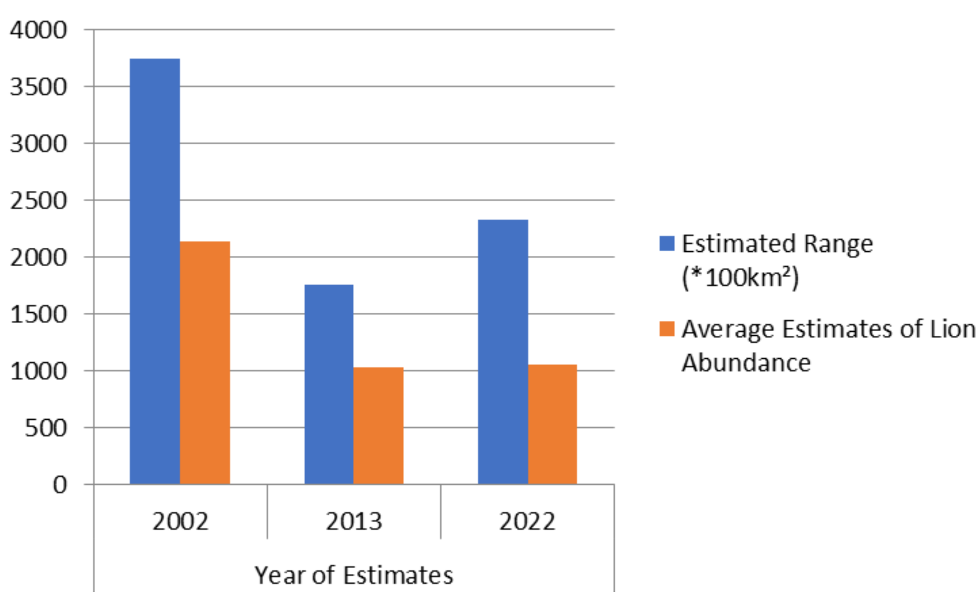

Figure 4. Estimates of African lion range and abundance by Chardonnet (2002), Riggio et al. (2013) and the current estimate.

be taken into consideration. In the north western, Bauer and Rskay (2016) conservatively assumed a density in the range of 1 to 2 lions per 100 km^2. On a total surface area of about 10,000 km^2, this would mean a population

Table 1. Lion areas, habitat size and population estimates for Ethiopia.

Lion area	Size (km^2)	Population
Boma-Gambella*	106,941	500
South Omo	22,483	200
Welmel-Genale	6,649	100
Ogaden	35,405	100
Awash	25,302	50
Bale	2,373	50
Nechisar	1,030	10

The greater proportion (82,541 km^2) is included in the South Sudan region and the population estimate for Gambella is 150.
Source: Riggio et al. (2013).

of 100 to 200 lions for the entire ecosystem, of which 27 to 54 would be in Alitash National Park. Wendim et al. (2015) recorded 53 lions in all of the six line transects of the proposed Mao-Komo National Park and extrapolated a population estimate of 413 considering 1000 km^2 (43% of the total area) as a suitable habitat. This population is believed to be overestimated since the extrapolation solely bases on suitable habitat and does not take the prey-predator relationship as well as associated ecological conditions. However, given the availability of prey, coupled with the intactness of the habitat in Mao-Komo, it is logical to assume the area is one of the lion strongholds in Ethiopia. Considering the direct sighting of 53 lions in the total sampled area (128.4 km^2) and significant number of prey populations, the area is believed to harbor sizeable lion population and thus it has to be exceptionally treated. Consequently, it can be conservatively proposed that density in the Mao-Komo ranges between 4 and 5 per 100 km^2 while the remaining adjacent ranges of Bejemiz, Dedessa and Dabus fall in the density 1-2 per 100 km^2.

The recent reports in the other side of LCU, Awash Valley also show dense distribution of some populations. For example, Siege et al. (2016) reported that 10-15 lions were estimated to inhabit in the 102.35 km^2 of Metehara sugarcane plantation. The dense distribution of the lions within the sugarcane plantation may be attributed to prey scarcity, fragmentation and associated perturbations of the surrounding natural habitat since larger carnivores are attracted by the prey populations of warthogs and wild pigs of agricultural areas as the prey diminishes in the natural ecosystem (Gebretensae et al., 2008). The abundance of lions in Bilen-Hertele Controlled Hunting Area (with 825 km^2 of an area), as estimated by Kebede et al. (2017) and Ewnetu et al. (2010) is 43 (±2) and 20 (±1), respectively; and this shows that 5.21 and 2.4 lions per 100 km^2, which largely exceeds the conservative assumption (1-2 lions per 100 km^2). This overestimation also stems from the simplistic approach of extrapolation that relies on crude assumption of suitable habitat without taking key ecological aspects into consideration.

Generally, efforts were made to assess some potential areas through which new locations for resident populations have been identified. It is however equally important to note that some of the populations in the former ranges especially in the protected areas are in deteriorating situation as their habitats are under increased anthropogenic pressure. For example, recent surveys in the Awash Valley and Gambella areas have indicated increased incidence of human-lion conflict and retaliatory killings by the local community and there is also significant fragmentation of habitats due to the ever-expanding cultivation areas (Wendim and Yadeta, 2013; Siege et al., 2016; Assefa and Teklu, 2017; Zerfu et al., 2019). Therefore, the present estimation of population needs to take into account the facts discussed earlier and the current population estimate of African lion in Ethiopia is summarized in Table 2.

Despite of the increase in the area coverage of ranges following the recent explorations, the current population estimate (915-1190 lions) does not show substantial difference with number of lions reported by Bauer and Van Der Merwe (2004) and Riggio et al. (2013) which estimated total of 1000 and 1030 lions, respectively. There is however significant decline (45-57%) as compared to the estimation made by Chardonnet (2002), in which 2144 lions were considered to occur in Ethiopia.

Potential threats to African lion

There are several threats and problems for lion conservation in Ethiopia. A problem analysis undertaken 12 years ago shows that habitat loss (mainly due to development that is incompatible with lion conservation), poaching, lack of prey and human-lion conflict all pose major threats for conservation of lions (Gebresenbet et al., 2009). The lion is classified as vulnerable on the IUCN Red List of Threatened species, with their range reduced by 8% of historical range (Bauer et al., 2015). The leading causes of their continent-wide decline are indiscriminate killing (often related to conflict), habitat

Table 2. The present lion areas, habitat size and population estimates for Ethiopia.

Lion area/Habitat patch	Size (km^2)	Population	Year of estimate	Associated IUCN LCU
Alitash National Park	2666	27-54*	2016, 2022	N/A
Mao-Komo, Bejemis and Dedessa Areas and their surroundings	29,000	162-255**	2015, 2018, 2022	N/A
Gambella	24,400	150*	2013, 2022	Boma-Gambella
South Omo and Gibe Valley	20,000	170-200*	2013, 2022	South Omo
Borana	15,000	50-100*	2021, 2022	N/A
Gerale-Dawa	4,000	40-80*	2021, 2022	N/A
Welmel-Genale	6,649	100*	2013, 2022	Welmel-Genale
Ogaden and Shebelle	100,000	100*	2013, 2022	Ogaden
Awash	25,000	50*	2013, 2022	Awash
Bale	3,000	30*	2013, 2022	Bale
Eastern Hararghe	3,500	35-70*	2021, 2022	N/A
Total population estimate	-	914-1189	-	-
	-	~915-1190	-	-

*Population extrapolated from the density 1-2 lions per 100 km^2 (current estimates made using the extrapolation adopted by Bauer and Van Der Merwe (2004), estimates made by Riggio et al. (2013), Bauer and Rskay (2016) and Yirga et al. (2021)). **Population extrapolated from medium density of 4-5 lions per 100 km^2 (Maokomo) and low density 1-2 lions per 100 km^2 (Bejemis and Dedessa) (based on reports of Yadeta and Hailu (2013), Wendim et al. (2015) and Wendim (2018)).

loss, prey base depletion and trade (Bauer et al. 2015; Riggio et al., 2013; Yirga et al., 2017).

Like the case of other countries of Africa, suitable lion habitats in many of its former ranges in Ethiopia have declined. Human and livestock population growth, settlement and agricultural expansion and the ramifications of economic development have had cumulative negative impacts on the natural habitat and populations of lions and their prey. Furthermore, poaching of the wild prey population and the existing expansion of livestock where the wild grazers progressively are being replaced by domestic ones has largely affected the roles of lions in the ecosystem. Besides, increased fragmentation of wildlands results in lack of habitat segregation and inter-specific competition among the larger carnivores and this in turn, brings about considerable lion population losses (Gebretensae et al., 2007).

Human-lion conflict has worsened over time and thus threatened the usual co-existence between people and lion populations. The conflict has escalated and reached its maximum and devastating stage in the process of retaliatory attack. These have resulted in tremendous socio-economic and ecological losses. The human-lion conflict in Soro district of Hadiya zone, Zone 3 of the Afar Region and Liben zone of the Somali region is the best example where depredation cases of hundreds of livestock of various types and significant number of people by lions were reported (Gebretensae et al., 2007). Similar incidences have been encountered recently in the middle and lower Awash Valley (Wendim and Yadeta, 2013; Siege et al., 2016; Assefa and Teklu, 2017; Yirga et al., 2017) and in some cases reduction of the vermin animals could not reduce the prevalence of the problem. The underlying causes for the conflict are believed to be habitat loss and fragmentation, prey scarcity and erosion of the traditional systems among others (Gebretensae et al., 2007; IUCN SSC Cat Specialist Group, 2018).

Illegal captivity and trade is also considered as potential threat to the lion population in the horn of Africa. The case of illegal trade of larger carnivores including cheetahs and lions has been well-publicized. For instance, Amir (2006) has pointed out that lion is one of the illegal trade-affected species through the Somali smuggling route and export destinations where many hunters adopted new hunting and trapping techniques, and learned to care and handle live animals bound to be sold in foreign counties. Since the recent past, Ethiopia appears to be facing an escalating poaching and trafficking threat linked to organized crime and cross-border trafficking networks (Gebretensae and Gebremicael, 2018) and lion is one of the victims of the ever-increasing threat (Tessema et al., 2021).

Conservation status

One of the recommendations from the regional lion conservation workshops (IUCN, 2006) was that National Action Plans should be developed, in order to guide the implementation of conservation measures at a national level. In 2012, Ethiopia endorsed a National Action Plan to conserve its lion population and this species specific conservation strategy was developed using logical framework methodology, based on the information on potential threats and associated problems. After defining the vision and goal, lion conservation objectives were defined for each threat. These objectives were further operationalized by setting targets and by defining the activities needed to achieve them. Time frames and responsibilities for these activities were also identified (EWCA, 2012).

The goal of the strategy is: "*To secure, and where possible restore, sustainable lion populations throughout their present and potential range in Ethiopia, recognizing their potential to provide substantial social, cultural, ecological and economic benefits*" and under this goal, there are objectives that deal with five thematic areas, namely: management, mitigation, socio-economic, policy-land use and trade (Gebresenbet et al., 2009; EWCA, 2012).

Generally, there have been considerable limitations in delivering the outputs that meet the aforementioned objectives even though considerations were given to specific components of the lion conservation strategy. One of the reasons for this is the conservation approaches in Ethiopia are ecosystem focused ones since there is a need to save the key biodiversity areas using the limited resources (Kebede and Gebretensae, 2018).

CONCLUSION AND RECOMMENDATIONS

It is generally true that there is limited information on the status of lions in Ethiopia. However, the existing data from the field assessments conducted over the past two decades show that there are more ranges for African lions and these areas include the wildlands that were assumed as extirpated in the previous reports. Despite this fact, the lion numbers are still low and declining. It is generally assumed that African lions in Ethiopia have been under serious threat from various anthropogenic activities like habitat destruction, indiscriminate killing and illegal captivity. It is therefore recommended that there is a need to:

(1) Effectively implement the developed national action plan for lion conservation;
(2) Strengthen partnership and trans boundary protected area systems in order to enhance ecological connectivity between the major habitats of lions;
(3) Undertake field assessment to examine the status of existing populations in the conformed ranges in general and in the possible stronghold areas of Mao-Komo, Bejimez, Dedessa, Dawa-Genalle and Wabe-Shebelle areas in general;
(4) Establish national Red list category for the threatened species based on the final reports of the assessments; and
(5) Conduct a countrywide census to ascertain the current population of lions in Ethiopia.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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