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Full Length Research Paper

The economic significance of lion breeding operations in the South African Wildlife Industry

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Currently, the majority of land used in South Africa for wildlife by the private sector has been converted from livestock farms to game farms and covers more land than state-owned provincial and national parks conservation areas combined. One animal that stands out above most wildlife regarding its popularity is the lion. From a private land owners' point of view, lions are amongst the most sought after animals for photographic safaris and trophy hunting, leading to the increase of lion breeding and populations on private land to the point where the private sector is responsible for managing the largest portion of the lion population in South Africa. Therefore, the aim of this research is to determine the economic significance of lion breeding within the South African wildlife industry. Qualitative interviews were conducted with 21 breeders in South Africa. The results revealed that lion breeders contribute R500 million (US$ 42 million) annually to the South African economy. The contribution of this research is twofold. Firstly, it was the first time such research has been conducted amongst lion breeders, and secondly, it points to the economic significance of lion breeding regarding the amount spend by breeders as well as number of jobs maintained by this breeders.

Key words: Consumptive and non-consumptive wildlife tourism, economic significance, ecotourism, lion breeding, wildlife tourism.

INTRODUCTION

The wildlife industry in South Africa is currently conducted on a large scale with an estimated 9000 wildlife properties covering an area of approximately 18 million hectares, which is 2.2 times greater than the state-protected area network of the country (Van Hoven, 2005; Els, 2017). What makes South Africa's wildlife industry unique in the world is that wildlife can be privately owned (Du Plessis, 1997). The majority of today's land used for wildlife by the private sector in South Africa, has been converted from livestock and crop farms due to reasons such as wildlife developed an economic value, wherein the 1900s to 1960s that was no or very little value; it became more economically viable to keep and use wildlife for commercial purposes than livestock (Cloete et al., 2015); in the 1990s, the demand for an African safari experience expanded rapidly, and tourism started to flourish (Scriven and Eloff, 2003). Before this, wildlife was perceived as an undesirable competitor to livestock farming for limited grazing land. As it became clear that a much wider range of income possibilities could be

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generated from wildlife, landowners began to realise that the wildlife industry might be an alternative option to, for example, livestock farms or other agricultural activities such as crop farming (Du Plessis, 1997). Since then, the wildlife industry has expanded, and today, the wildlife industry in South Africa provides consumable activities, such as recreational hunting, trophy hunting, biltong and wildlife meat production as well as non-consumable activities, namely breeding of wildlife and ecotourism (game viewing, walking safaris, and photographic safaris).

One animal that stands out above most wildlife regarding its popularity for non-consumptive as well as consumptive use (Lindsey et al., 2007, 2012b; Higginbottom, 2004), is the lion. Historically, lions could be found all over the African, European and Asian continents. However, there has been a dramatic decline in lion distribution and numbers in Africa due to habitat destruction, poaching, killing to protect livestock, hunting and depletion of the prey base as well as the direct consequences of the bush meat trade (Bauer and Van der Merwe, 2004; Bauer et al., 2008).

In the case of South Africa, lions had been eradicated from much of their historical range by the 1900s (Nowell and Jackson, 1996). Fortunately for South Africa, in the early 1990s lions were reintroduced into several reserves and national parks to increase their numbers (Funston, 2008; Slotow and Hunter, 2009), and today the Kruger National Park, Kgalagadi Transfrontier Park and Hluhluwe-iMfolozi Game Reserve are seen as specific strongholds for lions in South Africa (Government Gazette, 2015; Hayward et al., 2007; Hunter et al., 2007). From a private land owner's perspective, lions are among the most sought-after animals for photographic safaris and trophy hunting (Van der Merwe and Du Plessis, 2014; Saayman and Saayman, 2014), leading to the increase in populations on private land due to breeding and buying of lion prides.

Lion conservation management in South Africa is classified into four categories: Wild lions (largely unmanaged, which exist just in proclaimed national parks and game reserves); managed wild lions (all lions that have been re-introduced into smaller fenced reserves, <1000 km^2) and captive lions (bred exclusively to generate money and managers actively manipulate their breeding) (Funston and Levendal, 2015). Added to the South African captive lion population are animals kept in *ex-situ* facilities (e.g. sanctuaries, zoos and lion parks), where roaming is restricted, and where there is a high level of human contact (Funston and Levendal, 2015).

The wildlife industry (lion industry) in South Africa is largely located in the rural provinces of the country, predominantly the Northern Cape, North West, Limpopo, Free State, Mpumalanga, KwaZulu-Natal and Eastern Cape provinces (van der Merwe et al., 2007). Legislation further impacts on the South African private lion sector regarding where and how game species can be hosted. For example, most provinces allow private ownership of lions, but it is mainly the Free Sate and North West Provinces (80% of the hunting of lions is conducted in these two provinces, of which 50% are in Free State Province) that allow the hunting of lions (Williams et al., 2015; Els, 2017). In fact, no lions are hunted for trophy proposes in any of the national parks in South Africa, though limited hunting is allowed in some provincial state-owned reserves (Funston and Levendal, 2015). Therefore, lion hunting is predominantly conducted by the private wildlife industry on private land.

As the focus of this research is on determining the economic significance of lions, the researchers first had to identify what research had been previously conducted in this regard. Only a few studies pertaining to the economics of lions were found which included those by Lindsey et al. (2007, 2012a, b) and Cadman (2009). The research by Lindsey et al. (2007) focused on the economic and conservation significance of the trophy hunting industry in sub-Saharan Africa (Botswana, South Africa, Mozambique, Namibia, Tanzania, Botswana, Zimbabwe and Zambia), which included the hunting of lions. However, the latter revealed little about any economic significance of trophy hunting or that of lion hunting. In 2012, two studies were conducted by Lindsey et al. (2012a, b). The first study determined the significance of African lions for the financial viability of trophy hunting and the maintenance of wild land. This study investigated lion hunting in Mozambique, Tanzania, Zambia Zimbabwe and Namibia. The researchers determined that lion hunting generated the highest mean prices (US$24,000 to 71,000) of all trophy species (between 5 and 17% of gross trophy hunting income on national levels). The researchers concluded by indicating that if lion hunting was stopped or banned, trophy hunting, of which lion hunting forms an important part, could potentially become financially unviable across the research countries (59,538 km^2 land). The authors added by stating that the loss of lion hunting could have other potentially broader negative impacts such as reduction of competitiveness of wildlife-based land uses about ecologically unfavourable alternatives as well as a reduction in the tolerance for the species among communities where local people benefit from trophy hunting.

The second study by Lindsey et al. (2012b) determined the possible relationships between the South African captive-bred lion hunting industry and the hunting and conservation of lions elsewhere in Africa. The study's main aim was not to determine the economic impact or significance of lion hunting or breeding. They, however, indicated that the captive-bred lion hunting industry in South Africa had grown rapidly in the last couple of years, while the number of wild lions hunted in other African countries has declined. In 2009 and 2010, 833 and 682 lion trophies were exported from South Africa, respectively, more than double the combined export

(2009, 471; 2010, 318) from other African countries. The export of lion bones from South Africa also increased, and it was found that at least 645 (carcases) were exported in 2010, 75.0% of which went to Asia. In this study, they again only supplied the average price of lions hunted, which is US$37000 to 76000.

A report by Cadman (2009) commissioned by The National Council of SPCAs in South Africa (Society for the Prevention of Cruelty to Animals), however, indicated some economic results regarding lion hunting and breeding. In the report, Cadman (2009) indicated that lion hunting generated some R97,104,200 in 2007 and R49,240,240 in 2006. These figures reflect only the species fee, meaning no other costs were captured regarding travel and accommodation, for example. Cadman (2009) indicated that the average fee per lion is R152 920 and further stated that an estimated 900 people are employed in the lion industry. The report also indicates that lion breeders had invested some R700 million in land and infrastructural developments. The Cadman report, however, gives no clear indication of how this was conducted; therefore, leaving one with more questions than answers, especially on what the economic significance of the lion industry in South Africa is.

Further to this, none of these studies investigated the economic significance of lion breeding (from supply side point of view), except Cadman, but it lacks a sound methodology. Lion breeding and hunting have also featured in the media, notably so in the documentary "*Blood lions*" and that of *'Cecil the Lion'* that created a great deal of negative publicity on the topic. All these aspects contribute to this study being conducted based on the question; what is the economic significance of lion breeding in South Africa, how many people are employed and how much it costs to breed them?

To breed lions is a complex operation. Firstly, the development of the appropriate infrastructure, which includes holding facilities, staff houses, proper fencing of hunting camps (minimum size of 1000 ha), roads, accommodation facilities, to name but a few, is required. Secondly, there are the operational costs that consist of general running costs (wages, salaries, water and electricity), marketing, licence fees and operation leases (Els, 2017). For this study, the researchers excluded capital intensive infrastructure for the analysis and simply used the operational cost to determine the economic significance of the lion breeding industry. The reason for this was that infrastructure development differed significantly from farm to farm and did not take place within the year of the analysis (2016) (which is important for determining economic significance) as capital developments normally take place over several years as the product develops.

Determining the said significance in this research was undertaken because it measures the scale of the economic activity and, as a result, provides useful information when trade-offs are involved (Crompton, 2006). Economic significance is one of the numerous ways to define and measure value. Although other types of value are often important, this kind of significance is useful to consider when making economic choices that involve trade-offs in allocating resources. Economic significance is a measure of the importance of the finding in supporting or disproving one's hypotheses (Ecosystem Valuation, 2015), but it does not evaluate any loss in economic activity if it did not take place. Rather, it measures the size of the economic activity and, based on this, provides useful information when trade-offs are involved (Crompton, 2006).

Therefore, the aim of this research is to determine the economic significance of lion breeding within the South African wildlife industry.

METHODS

Data collection

Qualitative research was conducted using structured interviews. According to Creswell (2013), qualitative research is an approach to exploring and understanding the meaning individuals or groups ascribe to a social or human problem. This approach involves emerging questions and procedures; data are typically collected in the respondents setting; data analyses are inductively built from particulars to general themes (Creswell, 2013).

Sampling

The interviewed population consisted of members of the South African Predators Association (SAPA). For the purpose of this study, the focus was on lion breeders, lion traders and lion owners in South Africa. Stratified purposive sampling was used, where every third respondent on the SAPA members' list was chosen, from whom to gather data. The stratified purposive sampling approach was selected so that each respondent had an equal chance to be chosen and because resources for this study were limited. According to Patton (2002), purposive sampling is a technique used widely for most effective use, in such a case. According to Nieuwenhuis (2007), this form of sampling means that respondents are selected according to a preselected criterion relevant to a specific research question; in this case, it referred to the lion farmers on the given list.

Interview instrument

This qualitative interview instrument was newly developed, based on work conducted by Van der Merwe et al. (2011) and Saayman and Van der Merwe (2003). The interview instrument consisted mostly of closed response questions and a few open-ended questions. It contained three main sections: Demographic (for example, age and the highest level of qualification), development (number of lions and variations of lions on your establishment), economic (cost per month to operate lion facilities and the average price per lion) and management (size of camps and the number of employees).

A letter by the president of SAPA was sent to SAPA members to explain the aim of the research and also to indicate that SAPA management does endorse the research. Members were informed that they would be contacted telephonically. The members of SAPA were interviewed from June 2015 to September 2016, using telephonic or face to face interviews. Members were telephoned and again what the aim of the research is explained to them, and if agreed to be interviewed, the researcher continued with the interview. If the member is not willing to participate, the following member on the list was selected. Some of the respondents indicated that they preferred face-to-face interviews; in these cases, the researcher visited the respondents' farms and conducted the interviews. Of the 146 active SAPA members, interviews were carried out with 22 active SAPA members, resulting in 15% (n=22) of the total population.

According to Holloway and Wheeler (2002), trustworthiness in qualitative research can be defined as an "indication of methodological soundness and adequacy". Methods that were used in this study to establish trustworthiness include the following: Credibility (credibility was ensured by establishing well-researched methods and choosing a research design that fitted the research question); transferability (the researcher provided the respondents with a full and purposeful account of the research question and research design) and dependability (through the research design and its implementation, data gathering and the reflective appraisal of the research) (Lincoln and Guba, 1985).

Data analysis

The following data analysis was conducted. Microsoft Office Excel 2007 was used to capture the data collected from the research. To determine the economic significance (supply side) of lion breeding in the private wildlife industry, there are a variety of economic models or methods that could be used such as the Contingent Valuation Method (CV), the Travel Cost Method (TCM), the Social Cost-Benefit Analysis (SCBA), the Input-Output Model (I-O), the Computable General Equilibrium model (CGE) and the Social Accounting Matrix (SAM). According to Akkemik (2012), the selection of the modelling technique depends on the research question. For example, CGE models are used to determine the changes in supply and demand shock (Oosterhaven and Fan, 2006). On the other hand, Social Accounting Matrix (SAM) models are utilised to determine the economic significance of a particular feature within the tourism sector.

The South African Social Accounting Matrix (SAM) model based on the Input-Output model was employed to determine the economic significance of the private lion industry. The SAM model is one of the most popular models, used by various analysts (Akkemik, 2012), and has been extensively utilised to analyse numerous issues such as energy (Akkemik, 2012; Hartono and Resosudarmo, 2008), fisheries (Seung and Waters, 2009), foreign direct investment (Harun et al., 2012), climate change (Pal et al., 2011) and tourism (Rossouw and Saayman, 2011; Akkemik, 2012; Li and Lian, 2010; Cloete and Rossouw, 2014) as well as various other issues.

The SAM is an extension of the Input-Output model. Input-Output (I-O) models are described as sets of equations that describe the components that link the output of one industry within all other industries in an economy. This model can be used to determine the impact of a factor within each industry and may provide more significant information than do measures of the mere income, output and employment (Broomhall, 1993). According to Cameron (2003), I-O analysis is a logical framework devised with the intention of evaluating the interconnection of industries in an economy. In their most primitive form, I-O models can be defined by a system of linear equations that describe the allocation of an industry's product throughout the economy. This model is a complete method to estimate the flow of money between sectors, sub-sectors, organisations, businesses and consumers, while researchers mentor the interdependence effects when applying the various multipliers (Reeves, 2002). The I-O model can measure precise effects of macroeconomic changes on the local economy and also examine the improvement that a particular sector of the local economy could achieve. These models may be tailored to be relevant for precise conditions and economies or applied to address economies of scale associated with changes of output (Reeves, 2002).

The inter-sectorial links in I-O models are expanded through SAM by identifying the link between production sectors and all institutions within the tourism economy (Akkermik, 2012). The SAM can be used to examine the interrelationship between production structure, income distribution and household expenditure (Pal et al., 2011). The SAM model stands out from various other models due to its ability to detail the supply and demand, as well as *who* benefits from increased spending. This is especially important since the distribution of income of a certain activity can shed light on the influence that it has on both inequality and poverty in the country. Furthermore, Jones (2010) indicates that various types of multipliers can be derived from SAM models to capture the direct, indirect and induced impacts on output.

The analysis of economic significance is determined by using the operational cost per year of a participant, which is converted to the associated increase in production, income and jobs in the provincial economy using economic multipliers from a Social Accounting Matrix (SAM) model. The multiplier measures the changes in economic activity due to a change in spending in the economy. The multiplier captures the direct, indirect and induced effect of an increase in spending. The direct effect is the initial change in economic activity due to the spending, while the indirect effect measures the increase in production in other sectors due to their linkage with the direct activity sectors. The induced effect measures the increase in economic activity due to an increase in household income. It should be noted that the full effect is not immediate, but will only be realised over time (Pal et al., 2011).

The SAM multiplier approach makes use of specific multipliers for each cost-related subdivision. Costs are converted into the associated increase in output and income through the multipliers, while secondary effects are determined as the spending of a participant circulated through the national economy. The 2012 National Social Accounting Matrix (SAM) was used to determine the direct (spending by breeder on fencing) and indirect impact (fencing company pays their suppliers and employees) of a typical lion breeding farm in the country. The 2012 SAM consists of 62 activities, 140 commodities and 14 different household types based on income levels (Van Seventer et al. 2016).

RESULTS

The results from this study are discussed in three sections; firstly, the socio-demographic profile of participants; secondly, the operational cost of lion breeders; and thirdly, the household income.

Socio-demographic profile

The socio-demographic profile of the participants who formed part of the research was based on age, gender, home language, the highest level of education, training and province where situated. The majority of participants were male (77%), while a small percentage of participants were female (23%). The average age of the participants was 51 years of age, with the most commonly spoken language being Afrikaans (77%), followed by English (18%) and German (5%). It was clear from Table 1 that the majority of participants were well educated. Thirty-two percent (32%) of participants held a technical diploma/degree, 27% had attained a university degree or a postgraduate degree, 27% held a matric

Table 1. Socio demographic profile of lion breeders.

Category	Profile	Percentage per category
Age (years)	30-40	10
	41-50	29
	51-60	51
	61-70	5
	71-80	5
	Average age: 51	
Gender	Male	77
	Female	23
Language	Afrikaans	77
	English	18
	Other: German	5
Highest level of education	Some high school	14
	Matrix	27
	Tech diploma/degree	32
	University degree or postgraduate degree	27
Province where lion facilities are located	Free State	45
	North West	36
	Limpopo	14
	Northern Cape	5

Table 2. Generated cost of a lion breeding facility.

Statement	Percentage	ZAR
Running cost (wages, salaries, water and electricity, maintenance, repairs and administrative repairs)	63	112 266 000
Marketing	9	16 038 000
Licence fees	3	5 346 000
Insurance	6	10 692 000
Operating lease	6	10 692 000
General department	13	23166000
Total	100	178 200 000

qualification, while 14% had achieved a high school grade. The research shows (Table 1) that the largest percentage of participants are located in the Free State Province (45%), followed by the North West Province (36%) while a small proportion of participants are situated in the Limpopo (14%) and Northern Cape Provinces (5%).

Operational costs of a typical lion breeding establishment

The operational cost refers to recurring costs per year and therefore offers a reliable indication of the loss of economic activity in the absence of lion breeding. The breakdown of operational costs into various commodity items used to shock the SAM was obtained via the surveys. The operational cost of a typical lion breeding farm (Table 2) consists of the following items: Running costs (wages, salaries, water and electricity, maintenance, repairs and administrative repairs), marketing, licence fees, insurance, operating lease and general department.

Table 2 provides an indication of what lion breeders spend their operational costs on. A typical lion breeder spends 63% of operational cost on running costs per month, while 13% is expended on general aspects, 9% on marketing, 6% on insurance, 6% on an operational lease and a small percentage on licence fees (3%). Based on these amounts, the average running cost per lion breeding facility is approximately R50,000 per month.

Table 3. Impact of lion breeding operational activities on employment in the economy.

Sector	Total production (ZAR million)	Multiplier	Total labour	Percentage
Agriculture	2.702	3.90	11	1.7
Mining	10.546	0.66	7	1.1
Manufacturing	62.610	1.13	71	11.6
Electricity and water	114.888	0.14	16	2.7
Construction	27.706	5.54	154	25.1
Trade, accommodation and catering	13.003	4.53	59	9.6
Transport and communication	19.104	1.30	25	4.1
Financial and business services	74.285	2.85	212	34.6
Government	15.344	2.20	34	5.5
Personal and social services	9.040	2.76	25	4.1
Total	349.229		613	100

Table 4. Impact of lion breeding operational activities on employment in the economy.

Sector	Total production (ZAR million)	Multiplier	Total labour	Percentage
Agriculture	2.702	3.90	11	1.7
Mining	10.546	0.66	7	1.1
Manufacturing	62.610	1.13	71	11.6
Electricity and water	114.888	0.14	16	2.7
Construction	27.706	5.54	154	25.1
Trade, accommodation and catering	13.003	4.53	59	9.6
Transport and communication	19.104	1.30	25	4.1
Financial and business services	74.285	2.85	212	34.6
Government	15.344	2.20	34	5.5
Personal and social services	9.040	2.76	25	4.1
Total	349.229		613	100

This equates to R600,000 per year: If one multiplies this by the number of breeding facilities (297), the total amounts to R178 200 000 per year. This merely represents expenditure on operational costs per year, excluding the infrastructure costs.

The calculations of the direct, indirect and induced impacts of the operational cost per year of these farms are presented in Table 2. To determine the economic significance of lion breeding activities, all of the cost items were divided into one of the SAM commodity divisions (excluding salaries paid to workers). Using the multipliers, the subsequent indirect and induced effects on production in the economy of the direct spending by the total lion breeding industry were determined. The results were then aggregated into the main national accounts sector, as illustrated in Table 3. Production refers to the total turnover generated by each sector in the provincial economy. The production consists of two elements, the first being the transitional inputs by an activity and the second, the total value added that is generated by an activity

From Table 3, it is clear that the highest spending by lion breeders is on financial and business services. Therefore, the largest direct impacts are also in financial and business services (23.3%), manufacturing (28.1%), followed by construction (10.1%) and water and electricity (10.2%). Large indirect and induced impacts through the 'backwards linkages' are also experienced in the manufacturing sector, reflecting an indirect impact of R17.2 million and induced impact of R24.75 million. Agriculture (0.8%), personal and social services (2.6%) and mining (3.0%) recorded the lowest total impacts.

The aggregate multiplier can be derived by dividing the total impact by the direct impact. According to this calculation, the production multiplier is equal to R3.93, which signifies that every R1 spent by a lion breeder leads to an increase in production in the South African economy of R3.93.

The impact of the private lion industry on labour income is illustrated in Table 4, reflecting the effects on labour. In the production process, labour is an important factor and considered to be the most variable short-run input, so that any increase in production normally creates a positive impact. Table 4 indicates the effect of the private

Table 5. Impact of lion breeding operational activities on household income in the economy (ZAR million at 2012 prices).

Sector	Total production impact	Low income households	Middle income households	Total income households	Percentage
Agriculture	2.702	0.233	0.937	2.327	0.9
Mining	10.546	0.825	4.124	10.198	4.1
Manufacturing	62.610	4.847	21.996	52.810	21.2
Electricity and water	114.888	1.648	9.243	23.597	9.5
Construction	27.706	2.322	10.099	24.352	9.8
Trade, accommodation and catering	13.003	1.127	5.401	13.080	5.3
Transport and communication	19.104	1.210	6.594	16.416	6.6
Financial and business services	74.285	5.529	32.370	79.074	31.8
Government	15.344	1.380	7.662	18.180	7.3
Personal and social services	9.040	1.155	3.690	8.982	3.6
Total (ZAR million)	349.229	20.276	102.116	249.016	100

lion breeding industry's annual spending on job creation. The labour multiplier is derived from labour and output ratios and consequently illustrates the increase in the demand for labour due to an increase in production. Table 4 indicates that the private lion breeding industry is sustaining an additional 613 employees in the economy. This excludes workers who are working on the farms. Including such workers, a total of 1,162 jobs are sustained in the economy due to private lion breeding activities. Cadman (2009) indicated that 900 people are employed, and the current research showed more people are employed.

The sectors most affected regarding job opportunities are financial and business services (34.6%), construction (25.1%), and the manufacturing sector (11.6%).

Household income

Using the SAM multiplier, it was possible to determine the impact of spending at the level of families' income. To determine the impact, particular household income multipliers for each activity were calculated; these results were then multiplied by the values of the total sector's impact using the household allocation, from which it is possible to derive the benefit that low-, middle- and high-income families derive from lion breeding activities. From Table 5 it is clear that low-income households benefit to the extent of R20.3 million from the private lion industry.

Again, the total lion breeding industry's operational spending per year is used; it is evident that this spending creates economic activities in some sectors, which leads to income for households working in that sector. In total, the R88 million spent by lion breeding creates an income of just more than R249 million for the economy. This excludes the salaries/wages paid by the average farmer, which amount to an additional R67.4 million per year for the industry, making the industry's contribution to household income more than R316 million annually. The income multiplier is, therefore, R2.81, which means that for every R1 spent by a typical lion breeder, families earn up to R2.81 in the economy. The report by Cadman (2009) found that lion breeding contributes R78 million, including land. This research, therefore, found that lion breeding contributes more than that what was previously found, excluding land.

DISCUSSION

From the results of the research, the following discussions are presented.

Firstly, the research highlights the profile of a typical lion breeder. The average age of product owners is 51 years of age, indicating that they have been in the industry for some time, since it takes time and money to develop infrastructure for lion breeding. A significant percentage (59%) of respondents is well educated, which supports the notion that breeding of wildlife has become a science, and therefore is crucial in safeguarding the industry. Lion breeders can be regarded as entrepreneurs, and these results give us the profile of entrepreneurs in this industry. It is clear that lion breeding operations are small to medium-sized enterprises and these entrepreneurs contribute to job creation and development in rural areas.

Secondly, the economic contribution of these breeding facilities from a regional economic development point of view is important as that these facilities are mainly situated in the rural provinces of South Africa (Free State, North West, Limpopo and Northern Cape) where there is a need for economic development and job creation since they are some of the poorest provinces. It is, therefore, important for local government to support these types of developments in rural areas. One example is streamlining legislation and regulations in the wildlife industry as they differ from province to province to improve entrepreneurial opportunities and by doing this stimulate needed economic growth.

Thirdly, spending by lion breeders impacts several sectors in the respective provincial economies and consequently on the national economy. The sectors that benefit most as indicated are business services, construction, and the manufacturing sector. If lion breeding is banned or ceased to exist, these sectors will be impacted on especially in rural areas. This will result in fewer employment opportunities and reduction in new entrepreneurs in the breeding of wildlife.

To conclude, the study makes three contributions to current research; firstly, it was the first time that an investigation has focused on the breeders and the economic contribution they made, which is based on sound methodology; secondly, the research afforded greater insight into the world of lion breeding and who the breeders are (profile) and where they operate in South Africa; and thirdly, the research also contributes to conservation in South Africa, since the private lion industry does create healthy lion populations.

CONFLICTS OF INTERESTS

The author(s) have declared that there is no conflict of interest.

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REFERENCES

Akkemik, KA (2012). Assessing the importance of international tourism for the Turkish economy: A social accounting matrix analysis. Tourism Manage 33(4):790-801.

Bauer H, Van der Merwe S (2004). Inventory of free-ranging lions Panthera leo in Africa. Oryx, 38(1):26-31

Bauer H, Nowell K, Packer C (2008). Panthera leo, IUCN 2010. IUCN red list of threatened species. Version 2010.4. http:// www.iucnredlist.org/ apps/redlist/details/15951/0. Accessed 28 March' 2016

Broomhall D (1993). The use of multipliers in economic impact estimates. West Lafayette, Ind.: Purdue University. Cooperative Extension Service.

Cadman M (2009). Lions in captivity and lion hunting in South Africa. A report commissioned by the national council of SPCA'S. Alberton South Africa.

Cameron MJ (2003). The relationship between input-output (IO) analysis, social accounting Matrixes (SAM) and computable general equilibrium (CGE) models in a nutshell. Pretoria: Global Insight Southern Africa. (Unpublished working paper.)

Cloete PC, Rossouw R (2014) The South African wildlife ranching sector: A social accounting matrix Leontief multiplier analysis. Acta Commercii, 14(1):1-10

Cloete PC, Van der Merwe P, Saayman M (2015). Profitability of the game ranching industry in South Africa. 2nd ed. Caxton Publishers, Pretoria.

Creswell JW (2013). Research design: qualitative, quantitative and mixed methods approaches. 2nd ed. Sage Publications, California

Crompton JL (2006). Economic impact studies: Instruments for political shenanigans? J Travel Res 45(1):67-82.

Du Plessis PC (1997). Benuttingsvorme in die wildbedryf: 'n bestuursrekeningkundige evaluering. PhD, North-West university.

Ecosystem Valuation (2015). Basic concepts of economic value. http://www.Ecosystem valuation.org/1-01.htm. Accessed: 03 March 2015.

Els J (2017). Determining the economic significance of the lion industry in the private wildlife tourism sector. Master's Dissertation, North-West University.

Funston PJ, Levendal M (2015). Biodiversity management plan for lion (*Panthera Leo*) in South Africa. Government Gazette, 2 December 2015.

Funston PJ (2008). Conservation and management of lions in southern Africa: Status, threats, utilization and the restoration option. In B. Croes, H.H. De Jongh, & H., Bauer, (Eds.). Management and conservation of large carnivores in West and Central Africa. Leiden: Institute of Environmental Sciences. Pp. 109-131.

Hartono D, Resosudarmo BP (2008). The economy-wide impact of controlling energy consumption in Indonesia: An analysis using a social accounting matrix framework. Energy Policy 36(4):1404-1419

Harun M, Mat SHC, Jalil AZA (2012). Impact of foreign direct investment on income distribution in Malaysia: Social accounting matrix framework. Glob Rev Account Finance 3(1):32-42.

Hayward MW, Kerley GI, Adendorff J, Moolman LC, O'Brien J, Sholto-Douglas, A, Bissett C, Bean P, Fogarty A, Howarth D, Slater R, Kerley GIH (2007). The reintroduction of large carnivores to the Eastern Cape, South Africa: An assessment. Oryx 41(2):205-214.

Higginbottom K (2004). Wildlife Tourism: impacts, management and planning. Altoona Vic: Common Ground.

Holloway I, Wheeler S (2002). Qualitative research in nursing. Blackwell, London.

Hunter LTB, Pretorius K, Carlisle LC, Rickelton M, Walker C, Slotow R, Skinner JD (2007). Restoring lions Panthera leo to Northern KwaZulu-Natal, South Africa: Short-term biological and technical success but equivocal long-term conservation. Oryx 41(1):196-204

Jones S (2010). The economic contribution of tourism in Mozambique: Insights from a social accounting matrix. Dev. Southern Africa 27(5):679-696.

Li J, Lian C (2010). An empirical study on relative income determination of tourism industries with social accounting matrix of Jiangsu Province, China in 2002. Tourism Hosp. Res. 10(3):219-233.

Lincoln YS, Guba EG (1985). Naturalistic inquiry. Sage, California.

Lindsey P, Alexander R, Balme G, Midlane N, Craig J (2012a) Possible relationships between the South African captive-bred lion hunting industry and the hunting and conservation of lions elsewhere in Africa. S. Afr. J. Wildlife Res. 42(1):11-22.

Lindsey PA, Balme GA, Booth VR, Midlane N (2012b). The significance of African lions for the financial viability of trophy hunting and the maintenance of wild land. *PloS ONE*, *7*(1):e29332.

Lindsey PA, Roulet PA, Romanach SS (2007). Economic and conservation significance of the trophy hunting industry in sub-Saharan Africa. Biol Conserv *134*(4):455-469.

Nieuwenhuis J (2007). Qualitative research designs and data gathering techniques. In K. Maree (Ed.). First steps in research. Van Schaik Publishers, Pretoria, pp. 70-97.

Nowell K, Jackson P (Eds) (1996). Wild cats, status survey and conservation action plan. Gland, Switzerland: IUCN. (IUCN Cat Specialist Group.) https://portals.iucn.org/library/ sites/library/files/documents/1996-008.pdf.Accessed: 22 March 2015.

Oosterhaven J, Fan T (2006). Impact of international tourism on the Chinese economy. Int J Tourism Res 8(5):347-354.

Pal B, Pohit S, Roy J (2011). Impact of economic growth on climate change: an environmentally extended social accounting matrix (ESAM) based approach for India. (MPRA Paper no. 36540.) https://mpra.ub.uni-muenchen.de/36540/4/MPRA_paper_ 36540.pdf. Accessed: 16 May 2016.

Patton MQ (2002). Qualitative research and evaluation methods. 3rd ed. Sage, California.

Reeves M (2002). Measuring the economic and social impact of the arts: A review. London: Arts Council of England.

Rossouw R, Saayman M (2011). Assimilation of tourism satellite

accounts and applied general equilibrium models to inform tourism policy analysis. Tourism Econ 17(4):753-783.
Saayman M, Saayman A (2014). Who is willing to pay to see the Big 7? Tourism Econ 20(6):1181-1198.
Saayman M, Van der Merwe P (2003). Determining the profile of tourists visiting Pretoria National Zoo. Potchefstroom, S.A.: Institute for Tourism and Leisure Studies.
Scriven L, Eloff T (2003). Markets derived from nature tourism in South Africa and KwaZulu-Natal. In B. Aylward & E. Lutz (Eds.). Nature tourism, conservation, and development in KwaZulu-Natal, South *Africa*. World Bank Publishers, Washington, pp. 247-324.
Seung CK, Waters EC (2009). Measuring the economic linkage of Alaska fisheries: A supply-driven social accounting matrix (SDSAM) approach. Fisheries Res. 97(1):17-23.
Slotow R, Hunter LTB (2009). Reintroduction decisions taken at the incorrect social scale devalue their conservation contribution: The African lion in South Africa. In M.W. Hayward & M.J. Somers (Eds.), Reintroduction of Top-Order Predators. Wiley-Blackwell, Oxford. South Africa, pp. 41-73.
South Africa (2015). National Environmental Management: Biodiversity Act, 2004 (Act no. 10 of 2004) biodiversity management plan for African lion (Panthera leo). (Government Notice no, 351). Government Gazette, 38706, 17 April.
South Africa (2015) National Environmental Management: Biodiversity Act, 2004 (Act no. 10 of 2004). Government Notice no, 897). Government Gazette, 39185, 10 Sept.
Van der Merwe P, Du Plessis L (2014). Game farm and hunting tourism. AFRICAN SUN MeDIA, Stellenbosch.
Van der Merwe P, Saayman M, Krugell W (2007). The determinants of spending by biltong hunters. S. Afr. J. Econ. Manage Sci. 10(2):184-194.
Van Hoven W (2005). Ecotourism and game ranching: why it works. (Paper delivered at the Ecotourism South Africa Confex at the Indaba Hotel Johannesburg South Africa on the 9-11 November 2005) Johannesburg (Unpublished).
Van Seventer D, Hartley F, Gabriel S, Davies R.H (2016). A 2012 Social Accounting Matrix (SAM) for South Africa (No. 2016/26). WIDER Working Paper.
Williams V, Newton D, Loveridge A, Macdonald D (2015). Bones of contention: An assessment of the South African trade in African Lion *Panthera Leo* bones and other body parts. https://www.wildcru.org/wp-content/uploads/2015/07/Bones_of_contention.pdf Accessed: 15 August 2016.

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Population structure and feeding ecology of Guereza (*Colobus guereza*) in Borena-Sayint National Park, northern Ethiopia

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Population size, structure, activity time budget and feeding behavior of Guereza (*Colobus guereza*) were studied in Borena-Sayint National Park (BSNP), Ethiopia, from August 2008 to March 2009. Line transect survey technique was applied to investigate the population size and structure. Guerezas were observed only in the forest habitat. The mean group size, group density and group encounter rate in the forest habitat were 7.7 individuals, 14.8 groups per km^2 and 1.43 groups per km, respectively. In addition, the majority of the groups contained one adult male. The total population was estimated to be 2170 individuals. The population was skewed towards females. The ratio of male to female, young to adult and infant to female were 1.0:1.45, 1.0:4.16 and 1.0:4.9, respectively. The age structure was 47.9% adult, 32.7% sub-adult, 11.5% young, and 7.9% infant. No significant variation was observed in group size between seasons. Gureza consumed 31 plant species which consisted of 15 trees, 12 shrubs and 4 herbs. *Dombeya torrida* and *Olinia rochetiana* were the most consumed plant species which accounted for 18.2 and 12.6% of the diet of guereza. Leaves comprised of the largest proportion of the food items consumed (71.6%). Their diurnal activity is dominated by resting periods. This study contributes greatly to add information on the status of guereza in Ethiopia, and for its conservation and management.

Key words: Activity, age structure, Borena-Sayint, diet, guereza.

INTRODUCTION

The Ethiopian highlands are extremely rugged and varied, with some regions characterized by steep escarpments and deep valleys (Yalden, 1983). The Ethiopian biodiversity has high level of endemicity that needs much attention from government officials and other stakeholders for conservation because of the presence of a very diverse set of ecosystems (Bekele and Yalden, 2013). The country possesses high diversity of flora and fauna that occurs throughout the highland and lowland areas. Ethiopia consists of 315 species of mammals, out of these about 50 are endemic (Bekele and Yalden, 2013). So far, 11 species of primates are known to occur in Ethiopia (Yalden and Largen, 1992), and more are being discovered (Mekonnen et al., 2012).

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The colobine monkeys are found in Africa and Asia (Fashing, 2006). The African colobines can be split into three genera and 15 species (Groves 2007), which include *Colobus* (five species of black-and-white monkeys). These colobines occur in Africa, and inhabit many of the forested regions of Equatorial and West Africa (Fashing, 2006). Most species of the genus *Colobus* are identified by differences in their pelage. *C. guereza* (guereza) is one of the five species of the genus *Colobus* (Groves, 2007). This species is widely distributed across eastern and western Africa (Groves, 2005; Kingdon et al., 2008).

Guerezas are medium-sized, black and white arboreal monkeys (Kingdon et al., 2008). They can be found in moist and deciduous forests and savanna woodlands, often extending into highland or montane forests (Oates et al., 1994; Kim, 2002). Guerezas can exist in riparian (close to rivers), colonizing and upland forests, with some preference for water edges (Kim, 2002). They favor the main canopy levels in the forest and partially disturbed habitats, especially secondary forests. The preference of such habitat is associated with high species diversity of food trees in some secondary growth forests (Thomas, 1991). They can also be found in areas under human use, such as eucalyptus plantation (Harris and Chapman, 2007).

Even though Guerezas display great flexibility in their ecology, they exhibit little variability in social organization throughout their wide ranges (Newton and Dunbar, 1994). Their social groups are generally small and cohesive, ranging between 3 to 15 individuals (Bocian, 1997; Fashing, 1999). In general, group sizes tend to be larger in continuous forest and smaller in riparian or interrupted forest (von Hippel, 1996). In many cases, guereza groups include one adult male, several adult females and immature individuals. However, more than one adult male can be present as group size increases, and in several populations multi-male groups are common (Oates, 1994; Fashing, 2001a).

A population density estimate of a given species is vital for determining future conservation and management of that species (Muoria et al., 2003). Knowledge on the diurnal activity patterns and time budget of the animal can serve as an important tool in developing the species' conservation strategies (Kivai et al*.,* 2007). Information on daily activity time budget is also useful in the overall analysis of primate behavior and habitat use, and has been used widely in primate research (Di Fiore and Rodman, 2001).

Out of the eight subspecies of *Colobus guereza,* two subspecies, namely *C. g. guereza* and *C. g. gallarum,* are found in Ethiopia (Groves, 2007; Kingdon et al., 2008). Little is known about the status and behavioral ecology of guereza in Ethiopia. Dunbar and Dunbar (1974) have attempted to study the ecology and population dynamics of *C. guereza* in Ethiopia specifically in Bole Valley.

Hence, the present study aimed to investigate the population ecology of guereza in Borena-Sayint National Park, in northern Ethiopia. This study will provide base line information about the ecology and behavior of the animal for future in depth study. In addition, conservation initiatives may be launched for better protection of the animal and its habitat.

MATERIALS AND METHODS

Study area

The present study was carried out in Borena-Sayint National Park (BSNP), which is located 600 km north of Addis Ababa, Ethiopia, situated between 10°50'45.4"-1053'58.3" latitude and 38°40'28.4" - 38^{0}54'49" longitude (Figure 1). Currently, BSNP covers an area of 4,375 ha. It is part of the Eastern Afromontane Biodiversity Hotspot which is characterized by high species richness and endemism as well as severe human pressure (Mittermeier et al., 2005). The altitudinal range of BSNP in its current extent is 2,188 m to 3,732 m.. Due to the altitudinal range of the park, it comprises afromontane forest in this lower and sub-afroalpine in the middle and afroalpine vegetation types in the upper part of the park (EWNHS*,* 1996). The landscape of the park consists of rough topography, gorges, deeply incised valleys, steep escarpments, and strips of plateaus and cliffs (Ayalew et al., 2006). It harbors many mammalian species, including several primate species, including the eastern black and white colobus monkey (*Colobus guereza guereza*), hamadryas baboon (*Papio hamadryas*), grivet monkey (*Chlorocebus aethiops*) and gelada monkey (*Theropithecus gelada*). Farmland surrounds the park in all directions. The main agricultural products are cereal crops such as wheat (*Triticum aestivium*) and barely (*Hordeum vulgare*), and legumes such as lentils (*Lens culinaris*).

Preliminary survey

The study was conducted from August, 2008 to March, 2009 covering both wet and dry seasons. Before the period of actual data collection, a preliminary survey was conducted to get information regarding accessibility, climatic conditions, vegetation types, fauna, water sources, and the distribution of Guereza in the area. This period allowed the observer to become familiar with the forest environment within the home range of the studied groups and enabled to distinguish accurately the age/sex classes, recognize when the Guerezas performed different behavioral activities, and to know how close the observer could approach them. Three habitats were also identified: forest habitat, *Erica* woodland and *Festuca* grassland with *Lobelia*. Farmland habitat was ignored as the Guerezas were never seen in this habitat.

Population structure

Line transect survey technique was used to estimate the population size of guereza in BSNP (Peres, 1999; Plumptre, 2000). Line transects were used by stratified random sampling approach in which placement of transects was proportional to the area of different habitats where Guerezas were inhabited. Transects were measured and marked every 50 m (Chapman et al., 1988; Mekonnen et al., 2010). A total of 20 random transects (census zones), ranging from 1.5 to 2.5 km in length, were placed in the study area within the three habitat types. In the forest habitat, 16 transects were marked in five different specific census zones: 3

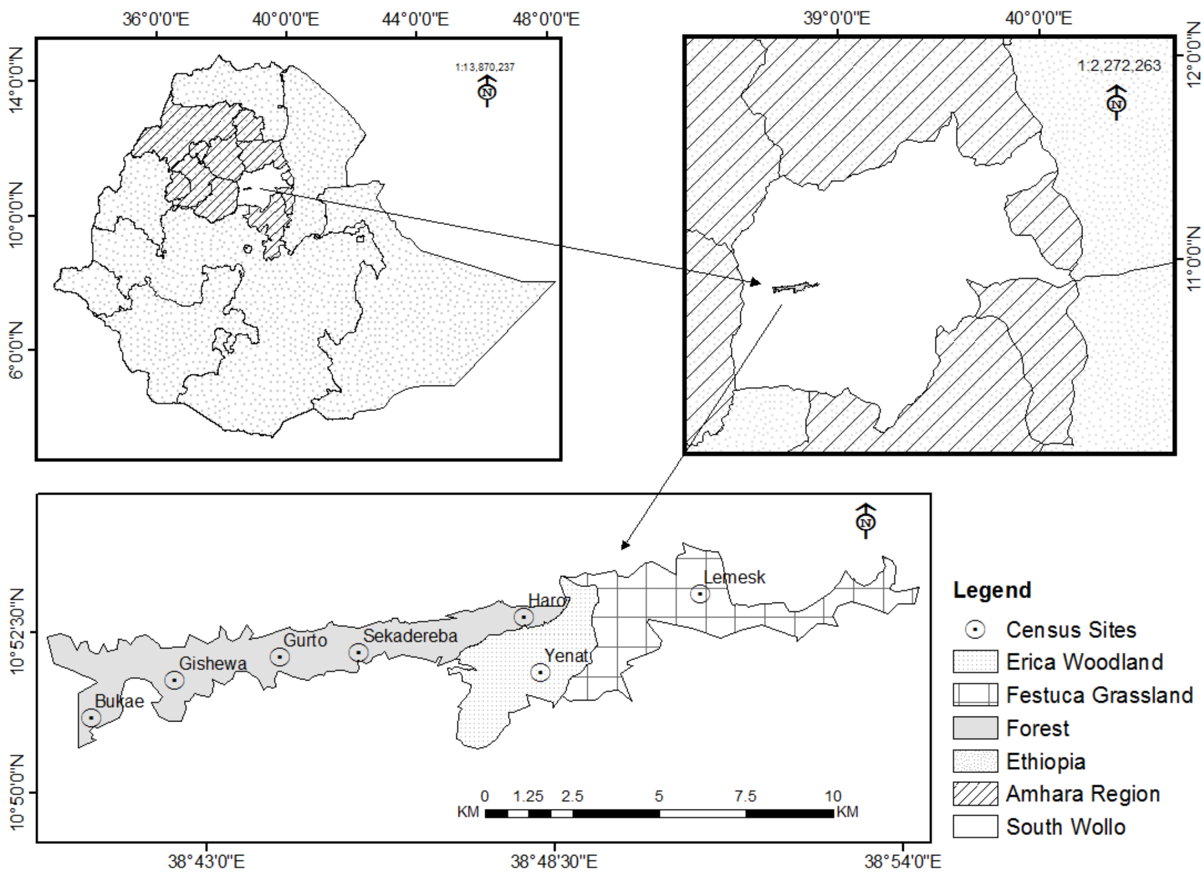

Figure 1. Map of the study area with the habitat types and census zone.

different transects in each of Bukae, Gishewa, Gurto and Haro areas, while 4 transects in Sekadereba area. In addition, two different transects were marked in each of *Erica* woodland and *Festuca* grassland with *Lobelia* habitat types. Each of these transects was surveyed with the help of experienced scouts during the wet and dry seasons in the morning (from 06:00 to 10:00 h) and afternoon (from 14:00 to 18:00 h) (Mekonnen et al., 2010) (Figure 1).

The observer recorded the time, group size (with age/sex), group spread, animal to observer distance, sighting angle, tree height and habitat types where Guerezas were detected (Fashing, 1999; Fashing and Cords, 2000). Animal to observer distance, and tree height were estimated by the observer. In addition, sighting angle was determined by the aid of compass. During the census, the observer walked on foot along a transect line with the help of Global Positioning System (GPS), and stopped frequently (every 5 min) to listen and scan the surrounding area. A walking pace of 2 km/hr was maintained (Peres, 1999).

In recording the number of individuals in a group, age and sex were determined primarily based on the work of Fashing (1999, 2001a) and Grimes (2000). Males have fused gray-colored ischial callosities encircled by an unbroken ring of white hair, but in females, the gray-colored ischial callosities are separate and the encircling ring of white hair is broken into two patches. The different age classes of guereza are identified on the basis of size, general appearance and behavior. Infants were small in size, clinging to the mother and dependent on her in all of the major group movements. At birth, infants are white in color with pink skin on face, ears, hands and feet, but gradually attain adult coloration within 3 to 4 months. They receive very intense attention from the other members of the group, especially from females. Young were small, but larger than infants, and roughly half the size of an adult female.

Activity patterns

Daily behavioral activities of Guereza were recorded by using instantaneous scan sampling method (Altmann, 1974) at 15 min intervals of 5 min duration starting from 06:00 to 18:00 h. Different activity types and dietary data were collected from two selected and partially habituated neighboring study groups of guereza for a total of 24 days per each season. The activities of individual Guereza were recorded by approaching the animals and observing them with naked eye or by the aid of binoculars to identify the specific types of activity they performed and food items consumed. The activity recorded for each individual was the first activity that sustained for 5 s once Guerezas came into view (Fashing, 1999, 2001a; Grimes, 2000). The record of the behavior of 1 individual during the scan represents 1 observation (Wong and Sicotte, 2007). Intense attention was given to avoid scanning the same guereza more than once in a given scan (Di Fiore, 2004). During each scan, the age/sex class of the visible individual Guerezas, along with the category of behavior they were seen performing, was recorded. Infants were excluded from scan sampling, and sex of young Guerezas was not identified. The following five exclusive behavioral categories were recorded on the standardized data sheet: resting, feeding, moving, socializing (playing, aggression, grooming and sexual activity), and other activities (defecation, urination, drinking

Table 1. Number of individuals of guereza observed at each sample site in different habitats.

Habitat types	No. of transects	Wet	Dry	Mean
Forest	-	-	-	-
Bukae	3	38	47	42.5
Gishewa	3	79	80	79.5
Gurto	3	52	69	60.5
Sekadereba	4	77	91	84
Haro	3	60	50	55
Erica woodland	2	0	0	0
Grassland	2	0	0	0
Total	20	306	337	321.5

or others) (Bocian, 1997; Grimes, 2000; Fashing, 2001a; Fashing et al., 2007). Feeding was recorded when the Guerezas were seen manipulating, masticating or placing food in their mouth.

Diet

During scan sampling, dietary data along with other behavioral activities were collected every 15 min interval from the focal groups. During the feeding activity of Guereza, the type of food item: young leaves, matured leaves, flowers, fruits, roots, bark, shoots, and wood (from dead plants) and the type of species consumed were recorded. The type of plant species consumed were given local names and taken to National Herbarium, Addis Ababa University for taxonomic identification.

Data analysis

Data collected during the survey were analyzed by using statistical package for social science (SPSS) 15.0 Software for Windows Evaluation Version. Statistical tests were two-tailed with 95% confidence intervals and level of rejection was set at p=0.05. Analysis of sex ratio and age structure was carried out using one-way analysis of variance (ANOVA). Density, encounter rates and mean group size of gureza population from the line transect survey were analyzed using "DISTANCE 5.0" software program (Buckland et al., 1993). The mean group size used to calculate density was recorded only from gureza groups counted during transect walks (Plumptre, 2000). The total population of gureza in the BSNP was estimated by multiplying the average individual density with the total area of suitable habitat (Chiarello, 2000; Mekonnen et al., 2010). Sex structure and age category were compared using Mann-Whitney U-test. Group size and distribution were also compared using Mann-Whitney U-test for independent samples. The differences in the amount of time spent for different activities at different seasons were also analyzed using Mann-Whitney U-test. Descriptive analysis of feeding time, plant species and plant parts consumed by gureza were used to identify the feeding behavior of the species.

RESULTS

Population structure

A total of 306 and 377 individuals were recorded from the forest habitat during the wet and dry seasons, respectively. The total population estimate for wet and dry seasons were 2145 and 2195 individuals, respectively. In addition, individual density/km^2 for wet and dry seasons were 112.9 and 115.5, respectively. Among the different sites sampled during the study period, the highest sample count was in the forest and no individuals were found in the *Erica* woodland and *Festuca* grassland habitats (Table 1). Analysis of the population size of gureza using Mann-Whitney U-test showed that there was no significant statistical difference between wet and dry seasons (P> 0.05).

Out of the average 321.5 individuals of gureza sighted during the observation period, 259 were adults and sub-adults, and the rest were young and infants (Figure 2). In addition, on the average, 47.9% of the individuals observed were adults, 32.66% sub-adults, 11.51% young and 7.93% infants. During the study period, more adults were counted than sub-adults, young and infants.

The ratio of adult male to adult female during wet and dry seasons was 1.0:2.75 and 1.0:2.68, respectively. The ratio of sub-adult female to sub-adult male was 1.0:1.71 and 1.0:1.67 during the wet and dry seasons, respectively. Analyses of the age structure and sex ratio for both adult and sub-adult males and females revealed that there was no significant difference (p> 0.05) in the age and sex distribution during the wet and dry seasons. In general, the ratios of male to female, young to adult and infant to female were 1.0:1.45, 1.0:4.16 and 1.0:4.9, respectively.

The average individual density was estimated to be 114.2 individuals per km^2 (range 82.5-148.1). The average encounter rate (groups/km) for gureza groups was 1.43. The total area of the forest habitat in the BSNP was 19 km^2. Hence, the total population of gureza in the BSNP was estimated to be 2170 individuals. The range of group size of gureza encountered was between 4 to 13 individuals. Group size never exceeded 13 individuals during the present observations (Table 2). Three multi-male groups, containing two males per group, were observed during the wet season, but during the dry season only one multi-male group was observed. All-male groups were never observed during both wet and dry seasons.

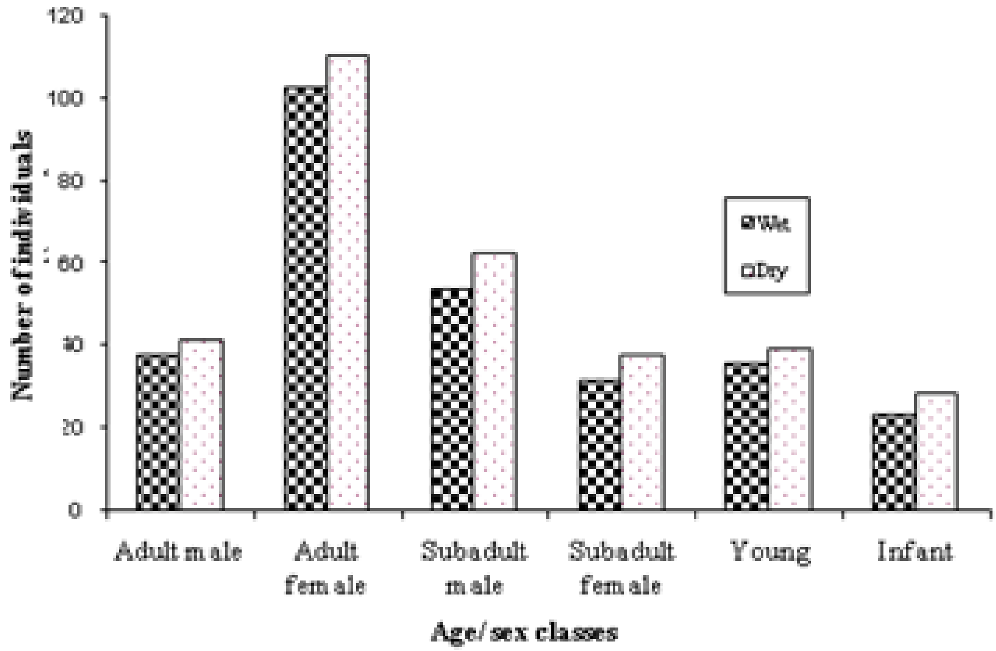

Figure 2. Sex and age structure of guereza population during wet and dry seasons.

Table 2. Group size of guereza observed during wet and dry seasons (Mean ± SE).

Season	Group size	Group density	Encounter rate (group/km)
Wet	7.82±0.38	14.4±2.78	1.34
Dry	7.61±0.26	15.2±2.84	1.52
Mean	7.71±0.23	14.8±2.21	1.43

Activity patterns

A total of 9600 individual behavioral records were made. Guerezas used their time resting (61.7%), feeding (22.6%), socializing (8.2%), moving (5.4%), and other activities (2.1%) such as urination and defecation. Guerezas on average spent more time resting (64.2±2.3%) during the wet season than the dry season (59.2±3.6%). Mann-Whitney U-test showed that there was a significant seasonal difference in resting between seasons (P< 0.0 5). Levels of feeding activity were closely related to resting. Guerezas on average spent more time feeding (23.8%±1.0%) during the dry season than the wet season (21.4±1.9%). However, there was no statistically significant difference between seasons in feeding (P> 0.05). Guerezas engaged in social activities (9.9±1.3%) more during the wet season than the dry season (6.5±2.4%). Mann-Whitney U-test showed that there was a significant seasonal difference in social activities between seasons (P< 0.05). Moving records were low followed by high resting records. Adult females usually initiate the moving activity of the group and members usually followed the same arboreal pathway. The amount of daily time spent in moving is 5.4±3.7%. Guerezas on average spent 2.5±0.3% of their moving time during the wet season and 8.3±2.8% during the dry season. There was a significant seasonal difference in moving (P< 0.05). They also spent more time engaged in other activities during the dry season 2.2 ±0.5% than the wet season 2.0±0.3%. However, there was no statistically significant difference between seasons in other activities (P> 0.05).

Diet

A total of 2153 feeding observations were recorded from scan sampling of guereza. The overall diet of guereza during the study period is shown in Figure 3. Young leaves contributed to 44.1±1.9% of the overall diet. Mature leaves and fruits were the second and third favored food items. The fourth and fifth contributors of guereza diet were bark and flowers. Shoots, roots and wood were consumed infrequently. However, they were never observed feeding on animal material.

The Mann-Whitney U test showed that there was a statistically significant difference in time spent for feeding

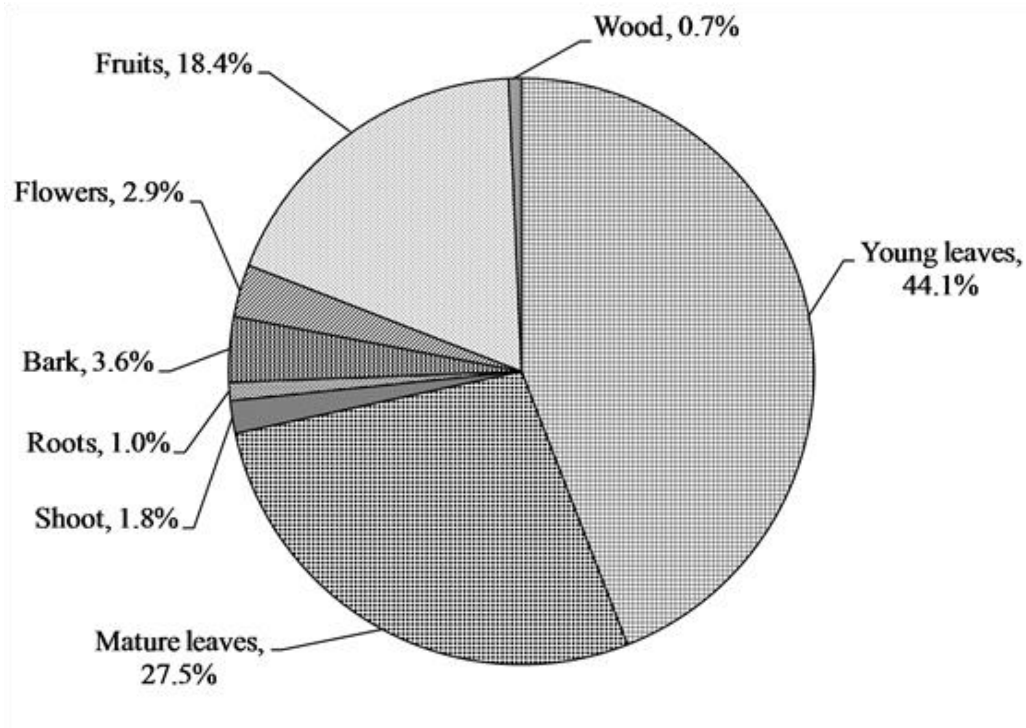

Figure 3. Percentage of feeding time devoted to different food items by guereza.

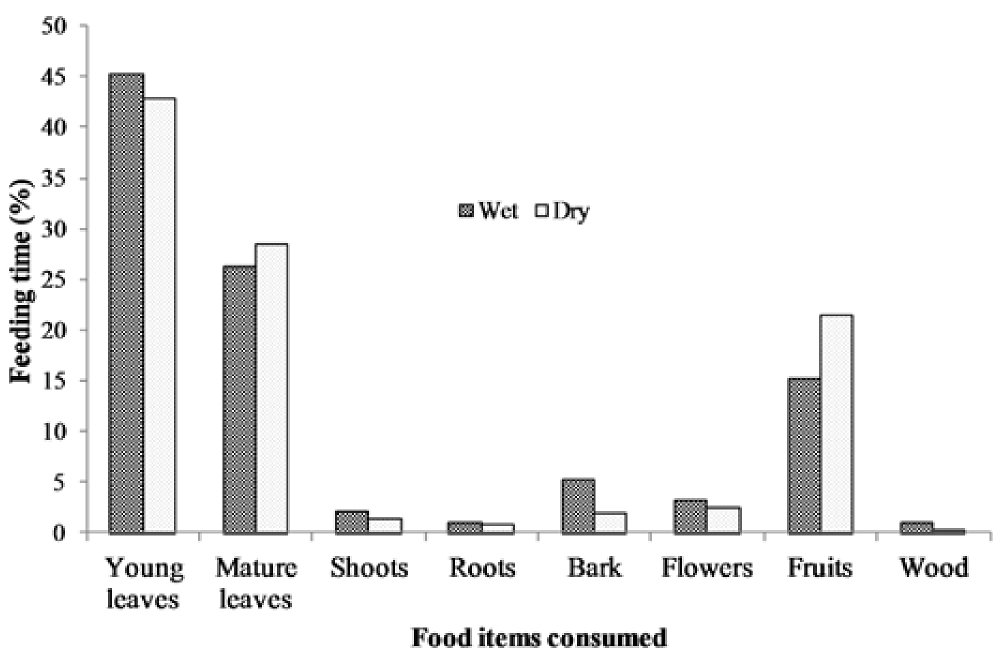

Figure 4. Seasonal percentage contribution of food items consumed by guereza.

on young leaves, mature leaves, bark, fruits and wood ($P< 0.05$) between wet and dry seasons. However, there was no significant difference ($P> 0.05$) between seasons in time spent feeding on shoots, roots and flowers (Figure 4). Guerezas consumed a total of 31 plant species that are grouped in 24 plant families. The percentage

Table 3. List of plant species, parts consumed and percentage contribution of the diet of guereza.

Local name	Species	Family	Life forms	Parts consumed	Time spent (%)
Wulkfa	*Dombeya torrida*	Sterculiaceae	Tree	YL, ML, FL	18.2
Tifae	*Olinia rochetiana*	Oliniaceae	Tree	YL, ML, FL, FR	12.6
Worer	*Teclea nobilis*	Rutaceae	Tree	YL, ML, FR, B	9.3
Dong	*Apodytes dimidiata*	Icacinaceae	Tree	YL, ML, FR	8.5
Shinet	*Myrica salicifolia*	Myricaceae	Tree	YL, ML B, FL,W	8.2
Tikur enchet	*Prunus africana*	Rosaceae	Tree	YL, ML, B, FL	5.8
Sesiy	*Albizia schimperiana*	Fabaceae	Tree	YL, ML, B	4.5
Sembo	*Ekebergia capensis*	Meliaceae	Tree	YL, ML, FR	4.2
Takma	*Rhus natalensis*	Anacardiaceae	Tree	YL, ML, B	3.6
Embis	*Allophylus abyssinicus*	Sapindaceae	Tree	YL, ML	3.2
Ameraro	*Discopodium penninervium*	Solanaceae	Shrub	YL, ML, SH, B, FL	2.6
Akelaho	*Maesa lanceolata*	Myrsinaceae	Shrub	YL, ML, FL	2.2
Lakuso	*Urera hypselodendron*	Urticaceae	Shrub	YL, S	2
Azamir	*Bersama abyssinica*	Melianthaceae	Tree	YL	1.9
Kombel	*Maytenus arbutifolia*	Celasteraceae	Shrub	YL, ML	1.7
Wude	*Galiniera saxifraga*	Rubiaceae	Tree	FL, FR	1.7
Atat	*Maytenus gracilipes*	Celasteraceae	Shrub	YL, ML	1.4
Gewra	*Myrsine melanophloeos*	Myrsinaceae	Tree	FR	1.2
Nech anfar	*Buddleja polystachya*	Loganiaceae	Shrub	YL	1.1
Woira	*Olea europea*	Oleaceae	Tree	YL, ML	1.1
Kechemo	*Myrsine africana*	Myrsinaceae	Shrub	YL, ML	0.9
Digta	*Calpurnia aurea*	Fabaceae	Shrub	YL, ML	0.8
Kega	*Rosa abyssinica*	Rosaceae	Shrub	FR	0.6
Koshm	*Dovyalis abyssinica*	Flacourtiaceae	Shrub	FR	0.6
Askuar	*Nuxia congesta*	Loganiaceae	Tree	FL	0.4
Embuacho	*Rumex nervosus*	Polygonaceae	Shrub	YL	0.4
Serdo	*Pennisetum clandestinum*	Poaceae	Herb	R	0.4
Gicha	*Cyperus sesquiflorus*	Cyperaceae	Herb	R	0.3
Maget	*Trifolium cryptopodium*	Fabaceae	Herb	R	0.3
Gorteb	*Plantago lanceolata*	Plantaginaceae	Herb	YL	0.2
Shekori	*Acanthus sennii*	Acanthaceae	Shrub	FL	0.1

YL: Young leaves; ML: Mature leaves; FL: Flowers; FR: Fruits; S: Shoots; B: Bark; R: Roots and W: wood.

contribution and food items consumed are given in Table 3 and the top ten consumed species are given in Figure 5. Out of the 31 plant species contributed for the overall diet of guereza, 15 species were trees, 12 were shrubs and 4 were herbs.

The highest contribution of the diet is from the family Sterculiaceae (18.2%), Oliniaceae (12.6%), Rutaceae (9.3%), Icacinaceae (8.5%) and Myricaceae (8.2%). The ten most consumed plants accounted 78.1% of the overall diet of guereza as shown in Figure 5. Based on the overall percentage contribution, *Dombeya torrida* was the most consumed plant species which accounted for 18.2%, *Olinia rochetiana* and *Teclea nobilis* ranked second and third (12.6 and 9.3%), respectively. The fourth and fifth ranked plant species were *Apodytes dimidiata* and *Myrica salicifolia* which accounted for 8.5% and 8.2% of the overall diet of guereza, respectively.

Based on the overall percentage contribution of plant parts to the diet of guereza from each species, young leaves of *D. torrida* were highly consumed accounting for 11.3%, while fruits of *O. rochetiana* accounted for 7.4%. Mature leaves of *D. torrida* and *Prunus africana* contributed for 10.1% of the diet of guereza. *M. salicifolia* wood exclusively contributed for 0.7% consumption of guereza. Plant species that were used by this monkey as sleeping and sheltering were *D. torrida*, *Ekebergia capensis*, *A. dimidiata*, *Hagenia abyssinica* and *P. africana*.

DISCUSSION

In the present study area, Guerezas inhabited only the forest habitat of BSNP. They were never observed in the

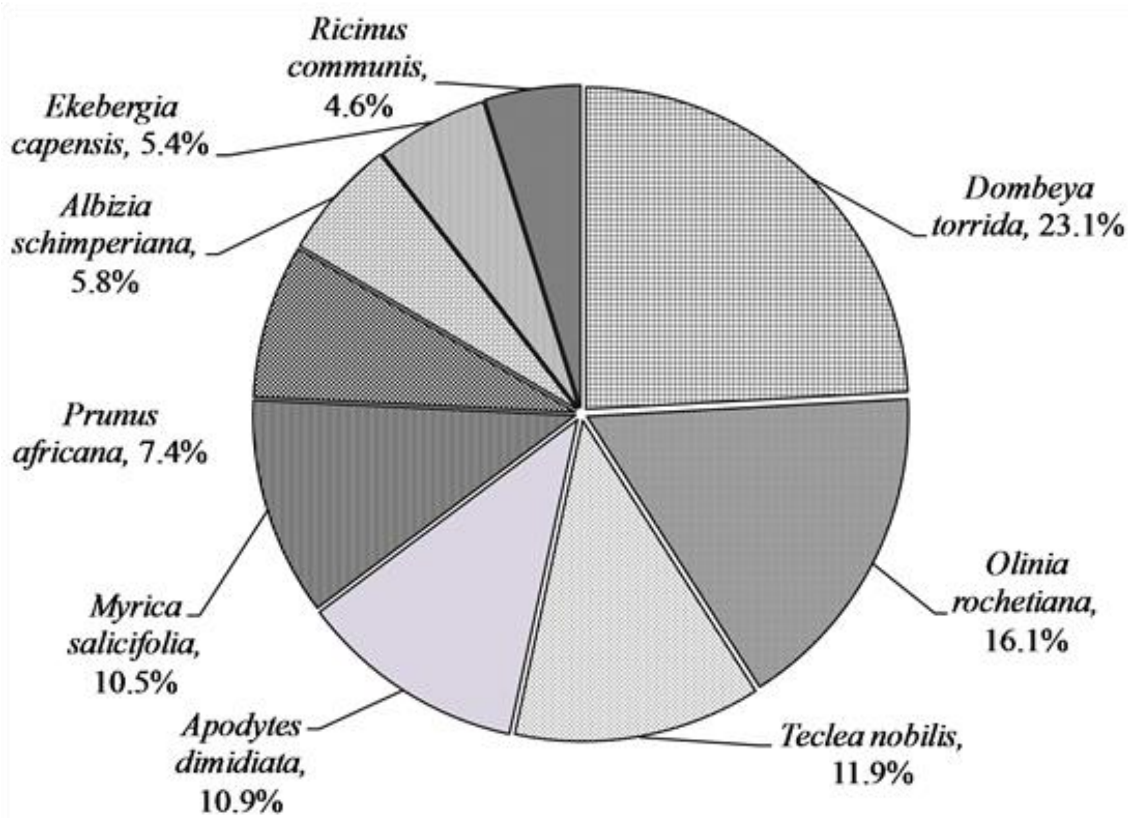

Figure 5. Percentage of the major ten plant species consumed by guereza during the study period.

Erica woodland and *Festuca* grassland habitats. Guerezas avoided these habitats may be due to the unsuitable leaves and grasses of *Erica arborea* and *Festuca* spp., respectively.

Sample count of Guereza individuals in BSNP revealed that there were 306 and 337 individuals during the wet and dry seasons, respectively. The increase in the number of individuals during the dry season might be due to an increase in visibility, presence of additional five groups throughout the census sites, and groups were observed feeding more in lower strata of the forest during the dry season. New born white infants were observed both during wet (3) and dry (5) seasons.

Infants were born throughout the year (Fashing, 1999; Harris and Monfort, 2006). Considering the census sites during the transect survey, differences in the number of individuals were observed between seasons in Gurto and Sekadereba areas. This is probably due to the availability of fruits and mature leaves of *O. rochetiana*, the young leaves of *Apodytes dimidiata* and *Ekebergia capensis,* and the mature leaves and flowers of *Dombeya torrida* during the dry season.

The census result of the present study showed that the individual and group densities, and mean group size of guereza were 114.2 individuals per km^2, 14.8 group per km^2 and 7.71 individuals, respectively. The density of guereza in BSNP is high compared to some other areas of Africa (Bocian, 1997; Grimes, 2000). This may be due to the availability and distribution of food trees in the present study area (Chapman and Chapman, 2002). In a number of colobine species, when population density increases home range size becomes compressed (Dunbar, 1987; Newton and Dunbar 1994). For instance, Fashing (2001b) found a significant negative correlation between population density and mean home range size.

Guereza groups in BSNP ranged from 4 to 13 individuals. However, the mean group size was 7.7 individuals. In most cases, one adult male, three adult females, two sub-adults, two young and/or infant are typical to the area (Dunbar, 1987; Bocian, 1997). A total of four multi-male groups (containing two males in a group) were observed during the study period. Three of them were during the wet and one was during the dry seasons. The three multi-male groups that were seen during the wet season might change to one male unit through group fission during the dry season (Bocian, 1997).

The number of adult males in guereza groups is related to habitat type (von Hippel, 1996). Larger multi-male groups usually live in continuous forests but smaller one male group likely resides in patchy forests. The group size of African colobines can be influenced by logging history, predation risk and feeding competition (Fashing, 2006). Guerezas are capable of conserving energy by traveling short distances each day, spending most of the day time resting, and feeding on relatively ubiquitous food items (Oates, 1977). Similarly, Guerezas in BSNP spend larger proportion of their time resting and feeding than engaging in socializing and moving.

Considering seasonal distribution of different behavioral activities, there were significant differences in time spent on resting, socializing and moving during wet and dry seasons. These seasonal variations might be corresponding with changes in the consumption of major dietary items or food availability and environmental factors (Oates, 1994; Bocian, 1997).

Guerezas spent more time resting and less time moving during the wet season than the dry season. This probably is due to the availability of young leaves during the wet season, as a result, they spent more time digesting and fermenting after consuming young leaves (Chivers, 1994). On the other hand, during the dry season, they had to travel relatively longer distances to obtain fruits of *O. rochetiana* and *Galiniera saxifraga,* young leaves of *A. dimidiata* and *E.capensis,* and mature leaves of *P. africana* and *Albizia schimperiana.* However, there was no significant difference between seasons in activity time allocation for feeding and other activities. This is due to the consumption on easily obtainable plant materials around their home ranges (Fashing, 2001b). In general, Guerezas spend more than half of their time resting leading inactive lifestyles throughout the year (Oates, 1977; Bocian, 1997; Fashing, 2001a).

The present study showed that different proportion of the hours of daylight was used by guereza for different activities. At BSNP, Guerezas mostly begin by exposing their body to the sun in resting condition and then followed by periods of feeding and resting (Bocian, 1997). This activity pattern may be related to the guereza's high fiber content of their diet (Oates, 1977) forcing them to spend more time on fermenting such food items in their specially designed multi-chambered stomach (Chivers, 1994). During the present study period, only one case of intragroup feeding competition was observed in one of the studied groups when individuals of the group competed to feed on flowers of *Acanthus sennii* during the dry season. This showed that intragroup aggression within guereza groups in BSNP was a rare phenomenon (Oates, 1977; Fashing, 2001a). Such phenomenon might occurs due to the relatively even distribution of most food items in their largely folivore diets (Fashing, 2006). In addition, smaller groups face less within group competition than larger groups (Bonaventura et al., 2008).

Classifying primate diets is usually accomplished by categorizing them from observations made over the total duration of the study, in terms of the proportion of feeding time spent consuming different plant parts (Chapman, 1987). However, categorization of primate species into folivores and frugivores is usually imprecise, given that a given species often depends on several kinds of food sources and that its diet varies locally and seasonally (Hill, 1997). Based on this categorization, Guerezas in BSNP are folivores since leaves accounted 71.6% of their overall diet. In addition, Kay and Davies (1994) noted that the physiology of the colobine gastrointestinal tract allows them to harvest abundant plant food sources such as mature leaves indicating folivory.

Members of Guereza groups in BSNP devoted more time consuming their favorite food, young leaves, rather than mature leaves. Wasserman and Chapman (2003) indicated that young leaves have more protein, low fiber content and are more easily digestible than mature leaves. They showed seasonal variation by consuming excess young leaves during the wet season as young leaves were abundant. Mature leaves were the second largest contributors of guereza diet in BSNP. These were consumed in excess during the dry season. This may be due to a relatively high consumption of mature leaves of *Dombeya torrida* and *Prunus africana*. In addition, young leaves were relatively scarce during the dry season and Guerezas fairly switch to the consumption of mature leaves.

Guerezas also spent portion of their time feeding on fruits after young and mature leaves. They spent more time feeding on fruits during the dry season due to the high availability of fruits and relatively low abundance of young leaves (Fashing, 2001b). *Olinia rochetiana* was the largest fruit contributor of guereza diet followed by *Teclea nobilis*. The fruits of *Olinia rochetiana* were abundant during the early dry season. Fruits make up substantial proportion of Guerezas diet (Fashing, 2001b). Bark was the next food item and consumed in higher proportion during the wet season. This may be due to the relatively higher moisture content of bark during the wet season (Bocian, 1997). In addition, wood was consumed by Guereza more during the wet season. However, flowers shoots and roots were consumed more or less in equal amount during both wet and dry seasons. But, Guerezas were never observed feeding on animal material; their diet consisted exclusively plant materials (Oates, 1977; Fashing, 2001b).

Guerezas have the most variable diets compared to other African colobines (Fashing, 2006). They heavily feed on leaves at some sites such as, the present study area; Kibale, Uganda (Harris, 2005); and Ituri, D.R. Congo (Bocian, 1997). In addition, a more varied diet of leaves and fruits or seeds at other sites was observed in Kakamega, Kenya (Fashing, 2001b). In general, the habitat in which the species lives has a profound influence on shaping its dietary niche (Xiang et al., 2007). A total of 31 plant species were consumed by Guerezas during the study period. However, 10 plant species accounted for 78.1% of the overall diet of guereza. Fashing (2001b) suggested that Guerezas are adapted to feed on relatively few food species to maintain low dietary species diversity even in species- rich rain forest environments. Considering the seasonal variation of these plant species, *Teclea nobilis* and *Rhus natalensis* were consumed more during the wet season. However, *Olinia rochetiana, Prunus africana* and *A. schimperiana* were consumed more during the dry season. This indicates that Guerezas in BSNP manage to live on easily available plant materials during both dry and wet seasons (Bocian, 1997; Fashing, 2001b).

Conclusion

The collected data during the present study period will provide important information on the population structure and behavioral ecology of Guerezas in Ethiopia. The total population of guereza in the study area was estimated to be 2170 individuals. Due to the presence of a variety of dietary materials during both wet and dry seasons, the population status of guereza groups in Denkoro forest is high. The vast majority of the groups were small containing only one adult male per group. Guerezas live only in the forest habitat of the present study area. *Erica* woodland and grassland habitats are found at a higher elevation and do not possess suitable dietary materials for Guereza. Resting and feeding are the dominant behavioral activities as the favorite dietary materials of Guereza are abundant. Hence, there are prolonged rest periods after the consumption of these food items. During the entire study period, Guerezas consumed a variety of food items from a total of 31 plant species. Young leaves, mature leaves, fruits, bark and flowers are accessed from a wide variety of plant species during the wet and dry seasons. As a result, they subsist on easily available dietary materials around their home ranges. Since Guerezas never engaged in crop raiding there was no conflict with the local people. However, the human settlements and agricultural lands are in close proximity with the park that may pose great threat to Guerezas and other animals by habitat destruction.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Altman J (1974). Observational study of sampling methods. *Behaviour* 49:227-267.

Ayalew A, Bekele T, Demissew S (2006). The undifferentiated Afro-montane forest of Denkoro in the central highland of Ethiopia: a floristic and structural analysis. SINET: Ethiop. J. Sci. 29:45-46.

Bekele A, Yalden DW (2013). Mammals of Ethiopia and Eritrea. AAU Printing Press, Addis Ababa.

Bocian CM (1997). Niche Separation of Black and White Colobus Monkeys (*Colobus angolensis* and *Colobus guereza*) in the Ituri Forest. Ph.D. dissertation. City University of New York, New York.

Bonaventura M, Visioli AB, Schino G (2008). Costs and benefits of group living in primates: group size effects on behaviour and demography. Anim. Behav. 76:1235-1247.

Buckland ST, Anderson DR, Burnham KP, Laake JL (1993). Distance Sampling. Estimating Abundance of Biological Populations. London: Chapman and Hall.

Chapman CA (1987). Flexibility in diets of three species of Costa Rican primates, Folia Primatol. 49:90-105.

Chapman CA, Chapman LJ (2002). Foraging challenges of red colobus monkeys: Influence of nutrients and secondary compounds. Comp. Biochem. Physiol. 133:861-875.

Chapman CA, Fedigan LM, Fedigan L (1988). A comparison of transect methods of estimating population densities of Costa Rican primates. Brenesia 30:67-80.

Chiarello AG (2000). Density and population size of mammals in remnants of Brazilian Atlantic Forrest. Conserv. Biol. 14:1649-1657.

Chivers DJ (1994). Functional anatomy of the gastrointestinal tract. In: Davies AG, Oates JF (Eds). Colobine Monkeys: Their Ecology, Behaviour and Evolution. Cambridge University Press. Cambridge, pp. 205-227.

Di Fiore A (2004). Diet and feeding ecology of woolly monkeys in a western Amazonian Rain Forest. Int. J. Primatol. 25:767-801.

Di Fiore A, Rodman PS (2001). Time allocation patterns of lowland woolly Monkeys (*Lagothrix lagotricha poeppigii*) in a Neotropical terra firma forest. Int. J. Primatol. 22:449-480.

Dunbar RIM (1987). Habitat quality, population dynamics, and group composition in colobus monkeys (*Colobus guereza*). Int. J. Primatol. 8:299-329.

Dunbar RIM, Dunbar EP (1974). Ecology and population dynamics of *Colobus guereza* in Ethiopia. *Folia. Primatol*. 21:188-208.

Ethiopian Wildlife and Natural History Society (EWNHS), 1996. Important Bird Areas of Ethiopia: A First Inventory. Addis Ababa: Ethiopian Wildlife and Natural History Society.

Fashing P (1999). The Behavioral Ecology of an African Colobine Monkey: Diet, Range Use and Patterns of Intergroup Aggression in Eastern Black and White Colobus Monkeys (*Colobus guereza*). Ph.D. dissertation, Columbia University, New York.

Fashing PJ (2001a). Activity and ranging patterns of Guerezas in the Kakamega Forest: intergroup variation and implications for intragroup feeding competition. Int. J. Primatol. 22:549-577.

Fashing PJ (2001b). Feeding ecology of the Guerezas in the Kakamega forest, Kenya: the importance of Moraceae fruit in their diet. Int. J. Primatol. 22:579-609.

Fashing PJ (2006). African colobine monkeys: Patterns between group-interaction. Prima. Perspect. 17:201-224.

Fashing PJ, Cords M (2000). Diurnal primate densities and biomass in the Kakamega Forest: an evaluation of census methods and a comparison with other forests. Am. J. Primatol. 50:139-152.

Fashing PJ, Mulindahabi F, Gakima J, Masozera M, Mununura I, Plumptre AJ, Nguyen N (2007). Activity and ranging patterns of *Colobus angolensis ruwenzorii* in Nyungwe Forest, Rwanda: possible costs of large group size. Int. J. Primatol. 28:529-550.

Grimes KH (2000). Guereza Dietary and Behavioural Patterns at the Entebbe Botanical Gardens. Ph.D. dissertation, The University of Calgary, Calgary.

Groves CP (2005). Order Primates. In: Wilson DE, Reeder DM (Eds). Mammal Species of the World: A Taxonomic and Geographic Reference. Johns Hopkins University Press. Baltimore, pp. 111-184.

Groves CP (2007). The taxonomy of the Colobinae of Africa. J. Anthropol. Sci. 85:7-34.

Harris TR (2005). Roaring, Intergroup Aggression and Feeding Competition in Black and White Colobus Monkeys (*Colobus guereza*) at Kanyawara, Kibale National Park, Uganda. Ph.D. dissertation, Yale

University, New Haven.
Harris TR, Chapman CA (2007). Variation in diet and ranging of black and white colobus monkeys in Kibale National Park, Uganda. Primates 48:208-221.
Harris TR, Monfort SL (2006). Mating behavior and endocrine profiles of wild black and white colobus monkeys (*Colobus guereza*): Toward an understanding of their life history and mating system. Am. J. Primatol. 68:383-396.
Hill DA (1997). Seasonal variation in the feeding behavior and diet of Japanese macaques (*Macaca fuscata yahui*) in lowland forest of Yakushima. Am. J. Primatol. 43:305-322.
Kay RNB, Davies AG (1994). Digestive physiology. In: Davies AG, Oates JF (Eds). Colobine Monkeys: Their Ecology, Behaviour and Evolution. Cambridge University Press. Cambridge, pp. 229-249.
Kim K (2002). *Colobus guereza* (On-line). Animal Diversity Web. Accessed july16, 2008 at http://animaldiversity.ummz.umich.edu/site/accunts/information/ Colobus_guereza.html.
Kingdon J, Struhsaker T, Oates JF, Hart JA, Groves CP (2008). *Colobus guereza*. In: IUCN 2008. 2008 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Accessed on 28 November, 2008.
Kivai SM, Muoria PK, Bekele A, Ogue N (2007). Activity budget and group dynamics in Grevy's zebra on Samburu rangelands, Kenya. Discov. Innov. 19:162-169.
Mekonnen A, Bekele A, Fashing PJ, Lernould JM, Atickem A, Stenseth NC (2012). Newly discovered Bale monkey populations in forest fragments in southern Ethiopia: evidence of crop raiding, hybridization with grivets and other conservation threats. Am. J. Primatatol. 74:423-432.
Mekonnen A, Bekele A, Hemson G, Teshome E , Atickem A (2010). Population size and habitat preference of the vulnerable Bale monkey Chlorocebus djamdjamensis in dobullu Forest and its distribution across the Bale Mountains, Ethiopia. Oryx, 44:558-563.
Mittermeier RA, Robles Gil P, Hoffmann M, Pilgrim J, Brooks T, Mittermeier CG, Lamoreux J, Da Fonseca GA (2005). Hotspots revisited: Earth's biologically richest and most threatened terrestrial ecoregions. Conservation International, Washington, DC.
Muoria PK, Karere GM, Moinde NN, Suleman MA (2003). Primate census and habitat evaluation in the Tana delta region, Kenya. Afr. J. Ecol. 41:157-163.
Newton PN, Dunbar RIM (1994). Colobine monkeys. In: Davies AG, Oates JF (Eds). Colobine Monkeys: Their Ecology, Behaviour and Evolution. Cambridge University Press. Cambridge, pp. 311-346.
Oates JF (1977). The guereza and its food. In: Clutton-Brock TH (Ed). Primate Ecology: Studies of Feeding and Ranging Behavior in Lemurs, Monkeys and Apes. Academic Press. New York, pp. 275-321.
Oates JF (1994). The natural history of African colobines. In: Davies AG, Oates JF (Eds). Colobine Monkeys: Their Ecology, Behaviour and Evolution, Cambridge University Press. Cambridge, pp. 75-128.
Oates JF, Davies AG, Delson E (1994). The diversity of living colobines. In: Davies AG, Oates JF (Eds.). Colobine Monkeys: Their Ecology, Behavior and Evolution. Cambridge University Press. Cambridge, pp. 45-73.
Peres CA (1999). General guidelines for standardizing line-transect surveys of tropical forest primates. Neotrop. Prim. 7:11-16.
Plumptre AJ (2000). Monitoring mammal populations with line transect techniques in African forests. J. Applied Ecol. 37:356-368.
Thomas SC (1991). Population densities and patterns of habitat use among anthropoid primates of the Ituri Forest, Zaïre. Biotropica 12:68-83.
von Hippel FA (1996). Interactions between overlapping multimale groups of black and white colobus monkeys (*Colobus guereza*) in the Kakamega Forest, Kenya. Am. J. Primatol. 38:193-209.
Wasserman MD, Chapman CA (2003). Determinants of colobine monkey abundance: the importance of food energy, protein and fibre content. J. Anim. Ecol. 72:650-659.
Wong NPS, Sicotte P (2007). Activity budget and ranging patterns of *Colobus vellerosus* in Forest Fragments in Central Ghana. *Folia. Primatol.* 78:245-254.
Xiang Z, Huo S, Xio W, Quan R, Grueter C (2007). Diet and feeding behavior of *Rhinopithecus bieti* at Xiaochangdu, Tibet: Adaptation to a marginal environment. Am. J. Primatol. 69:1141-1158.
Yalden DW (1983). The extent of high ground in Ethiopia compared to the rest of Africa. SINET*:* Ethiop. J. Sci. 6:35-39.
Yalden DW, Largen MJ (1992). The endemic mammals of Ethiopia. Mammal Rev. 22:115-150.

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Diversity and distribution of African indigenous vegetable species in Uganda

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African indigenous vegetable species (AIVS) provide a means of livelihood to many urban and peri-urban dwellers in Uganda. It was thus deemed necessary to understand the existing diversity and distribution of the traditional African vegetable species as a basis for recommending conservation and utilization strategies against biodiversity loss. A field survey was conducted in the four major agro-ecological zones of Uganda to provide information on a recent abundance of the various AIVS. Results from the survey showed that the Solanaceae (43.4%), Amaranthaceae (15.5%) and Malvaceae (11.6%) were the most prevalent families out of seven different families encountered. Twenty-three (23) species, a number lower than that initially reported in literature and distributed unevenly in the different regions were identified. Majority of the species were the indigenous rather than introduced vegetable species. Firstly, the study is informative of the superior importance of *Solanaceous* species compared to other AIVS. Secondly, the survey results indicate that the AIVS are becoming increasingly more important in Uganda than their introduced counterparts since all the 43.4% that composed the Solanaceae majority were of indigenous type. Research efforts should be devoted towards improved variety development and germplasm conservation to prevent a possible biodiversity loss of the most important AIVS for increased household incomes and nutrient security among the resource-poor majority in Uganda and other sub-Saharan Africa countries.

Key words: Crop biodiversity, germplasm collection, indigenous vegetables, species abundance.

INTRODUCTION

African indigenous vegetable species (AIVS) are useful locally available resources for the achievement of food security and for poverty alleviation among smallholder farmers in rural, peri-urban and urban areas in sub-Saharan Africa (Abukutsa- Onyango, 2014; Ebert, 2014). AIVS can be defined as those vegetable species that either originated in Africa or have stayed on the continent for such a long time in history that they are now indigenized (Kamga et al., 2016; Syfert et al., 2016). The AIVS, also commonly referred to as traditional African vegetables are primarily either wild or semi-domesticated vegetable species that are accustomed to and integrated among the diets, habits and traditions of different African communities (Ebert, 2014; FAO, 2013; Ojiewo et al., 2013). The traditional African vegetables are thus categorized into two based on origin; indigenous and introduced depending on whether they originated on the continent or from outside Africa, respectively (Kamga et al., 2016; Syfert et al., 2016; Von Grebmer et al., 2015). In the past, the introduced vegetables were the only category canonically known as commercial vegetable species; and the indigenous for subsistence use (Cernansky, 2015; Ojiewo et al., 2013). Over the years, farmers in Africa have picked a commercial interest in the indigenous species and such a trend is on an optimistic rise (Abukutsa-Onyango, 2014; Ebert, 2014; FAO, 2013; Pincus, 2015). The increasing commercial interest for AIVS brings hope for full utilization of these vegetables (Bisamaza and Banadda, 2017; Cernansky, 2015). The AIVS are reported to have higher levels of micronutrients and essential minerals as well as protein than the exotic or introduced vegetable species (Bisamaza and Banadda, 2017; Ojiewo et al., 2013; Pincus, 2015). The traditional African vegetables have thus been documented for multiple uses such as food, cash, medicinal, cultural and ornamental purposes (Abukutsa-Onyango, 2014; Ebert, 2014; Omulo, 2016). Other types of AIVS exist based on plant part used; mainly leafy, fruit, seed and root vegetables (Adeniji et al., 2012; Bationo-Kando et al., 2015; Borràs et al., 2015; Kouassi et al., 2014; Prohens et al., 2013). The most important AIVS in Uganda are consumed as leaves for instance *Solanum aethiopicum* 'Shum group', *Amaranthus* spp., *Abelmoschus esculentus* and *Hibiscus sabdarifa* (Omulo, 2016; Pincus, 2015). Elsewhere the fruit, seed and root vegetables are vitally important for food among other uses (Ebert, 2014; FAO, 2013).

There is a diversity of AIVS in Uganda such as amaranths (amaranths spp.), African eggplant (*S. aethiopicum*), and pumpkins (*Cucurbita* spp.) (http://afri-sol.org) and African nightshades (Pincus, 2015). By the year 1989, at least 160 species of traditional vegetables were reportedly collected from 11 agroecological zones in Uganda (Abukutsa-Onyango, 2014; Ebert, 2014). The wide of range of AIVS is due to favorable agroclimatic conditions (Abukutsa-Onyango, 2014; FAO, 2013). Eight years later, a similar survey documented only 34 species which indicates a biodiversity loss of about 79% attributable mainly to human activity, bush fires and prolonged drought (Alexandratos and Bruinsma, 2012). The rapid decline in diversity of the species is detrimental as it compromises their potential contribution towards food security and livelihood of many rural and urban smallholder farmers (Agoreyo et al., 2012; Alexandratos and Bruinsma, 2012; Ayaz et al., 2015; Stone et al., 2011). For example, *S. aethiopicum* 'Shum group' is an important commercial and subsistence crop in mainly urban and peri-urban areas of central Uganda (Pincus, 2015). The food security value of the AIVS is mainly due to their higher nutrient content compared to introduced vegetables (Agoreyo et al., 2012; Ayaz et al., 2015; Chinedu et al., 2011). It was thus deemed necessary to provide an update on the biological diversity and distribution of the traditional vegetable species (http://afri-sol.org/index.php/2016/09/15/launch-of-paepardfara-project2014-2017/). The specific objectives of this study included the following: 1) to assemble AIVS germplasm for conservation and use; 2) to understand the current diversity of AIVS; 3) to understand the agroecological distribution of the existing traditional vegetables in Uganda.

The documentation on availability and distribution of different species would inform stakeholders on the necessary mitigation measures against further biodiversity loss; and promote the utilization of most abundant species.

MATERIALS AND METHODS

A total of 129 samples of AIVS were collected from four major administrative regions (https://en.wikipedia.org/wiki/Regions_of_Uganda) that represent main agro-ecological zones of Uganda. The regions include the central, western, eastern and northern Uganda. The survey was carried out in April 2015. In each region one district was selected in which at least one sub-county was used for the ecogeographic survey based on eco-geography. Sampling was done at every 100 km, and then guided by a local administrator to lead the team to a specific community greatly engaged in vegetable growing. Figure 1 shows the survey locations (districts) per region as follows: Central (Mukono, Wakiso and Mpigi), Eastern (Jinja, Mbale and Kaberamaido), Northern (Gulu, Arua and Lira) and Western (Hoima, Kasese and Kabarole). Each district, one sub-county. In each of the survey sub-counties, a local agricultural extension agent guided the survey team to vegetable growing households. At each community, a focus group discussion (http://ctb.ku.edu/en/table-of-contents/assessment/assessing-community-needs-and resources/conduct-focus-groups/main) at local council (LC) I level was conducted and reference farmers were selected by the focus group to provide the germplasm samples. The accessions were obtained at the farmers homes for the seed in addition to

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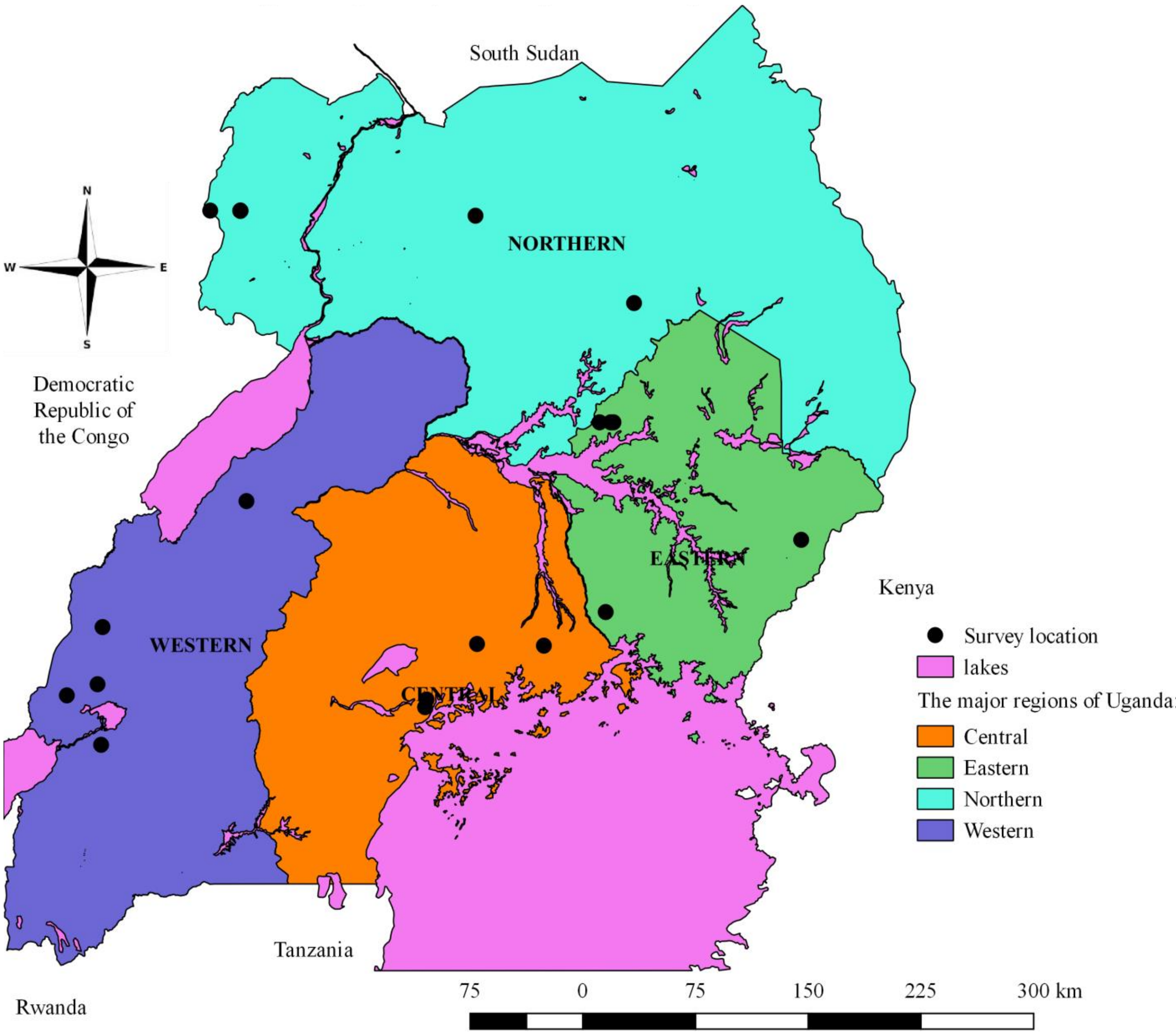

Figure 1. Map of Uganda showing some of the AIVS survey locations in 2015.

observation of the species in the field for identification. Both the vegetable plant species and farmer characteristics were taken record of. The vegetable seed samples were delivered at the Biology laboratory, Department of Agricultural and Biological Sciences at Uganda Christian University for germplasm conservation and use in follow-up studies such as morphological and molecular characterization; and variety improvement through breeding. Data collected on vegetable accession samples from the four regions was summarized in Microsoft Excel and analyzed using IBM SPSS Statistics v21 software for frequency of different vegetable species. Column graphs and pie-charts for species abundance per region were also generated in the Microsoft Excel. The survey map was generated in QGIS v2.14.0 (http://qgis.org/en/site/).

RESULTS

Families

All the samples collected belong to within seven plant families namely Amaranthaceae, Asparagaceae, Brassicae, Cucurbitaceae, Fabaceae, Malvaceae and Solanaceae. Of the 129 samples, the Solanaceae was the most abundant family at 43.4% followed by Amaranthaceae (15.5%) and Malvaceae (11.6%) (Figure 2). Family Brassicae was the least abundant at 1.6%, in the central region Solanceae was the most abundant

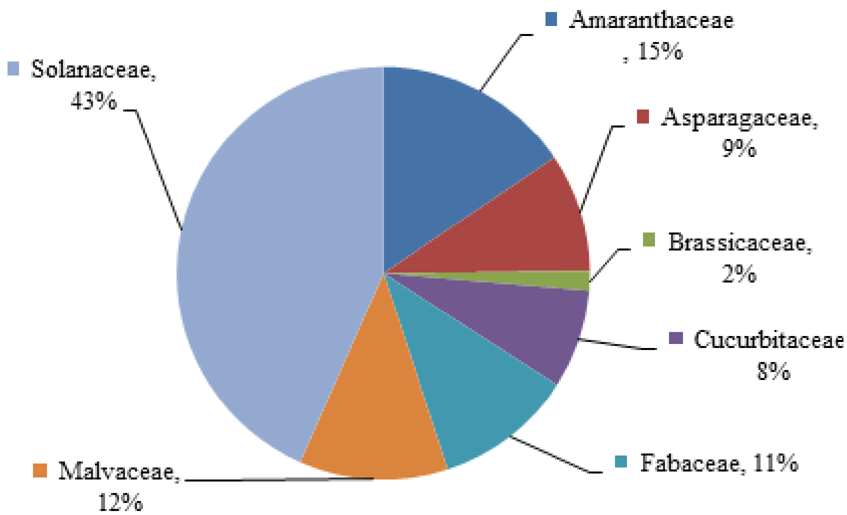

Figure 2. Overall abundance of AIVS families in Uganda in 2015.

Table 1. Regional distribution of AIVS families in Uganda in 2015.

Family	Number and proportion of samples per region								Total	
	Central		Eastern		Northern		Western			
	#	%	#	%	#	%	#	%	#	%
Amaranthaceae	4	3.1	8	6.2	4	3.1	4	3.1	20	15.5
Asparagaceae	1	0.8	7	5.4	4	3.1	0	0.0	12	9.3
Brassicaceae	0	0.0	0	0.0	2	1.6	0	0.0	2	1.6
Cucurbitaceae	1	0.8	4	3.1	4	3.1	1	0.8	10	7.8
Fabaceae	6	4.7	3	2.3	5	3.9	0	0.0	14	10.9
Malvaceae	0	0.0	0	0.0	15	11.6	0	0.0	15	11.6
Solanaceae	8	6.2	15	11.6	4	3.1	29	22.5	56	43.4
Total	20	15.5	37	28.7	38	29.5	34	26.4	129	100

#, Number of samples; %, percentage.

followed by Fabaceae and Amaranthaceae. Three most prevalent families in the Eastern were Solanaceae, Amaranthaceae and Asparagaceae. The most abundant families in Northern Uganda were Malvaceae followed by Fabaceae. The Western region had Solanaceae (22.5%) followed by Amaranthaceae (3.1%) and Cucurbitaceae (0.8%). The Northern region had the highest AIVS abundance mainly (Malvaceae) followed by Eastern (Solanaceae), Western (Solanaceae) and the Central (Solanaceae) (Table 1).

Genera

The samples encountered during the survey belonged to 13 genera and seven families. Overall, genus *Solanum* was the most prevalent at 38.8% followed by *Amaranthus* (15.5%). Other relatively highly prevalent genera were *Chlorophytum*, *Abelmoschus*, *Capsicum* and *Hibiscus* (Figure 3). The central region had *Solanum* (6.2%) and *Amaranthus* (3.1%) as the most prevalent genera. The Eastern had *Solanum* (10.1%), *Amaranthus* (6.2%), *Chlorophytum* (5.4%) and *Cucurbita* (3.1%) as the most abundant genera. *Abelmoschus* (7.8%) and *Hibiscus* (3.9%) were the most prevalent in Northern Uganda. In the Western region, genus *Solanum* was recorded as the most abundant at 19.4% followed by *Amaranthus* and *Capsicum* (Table 2).

Species

A total of 23 traditional vegetable species were encountered during the survey. *S. aethiopicum*,

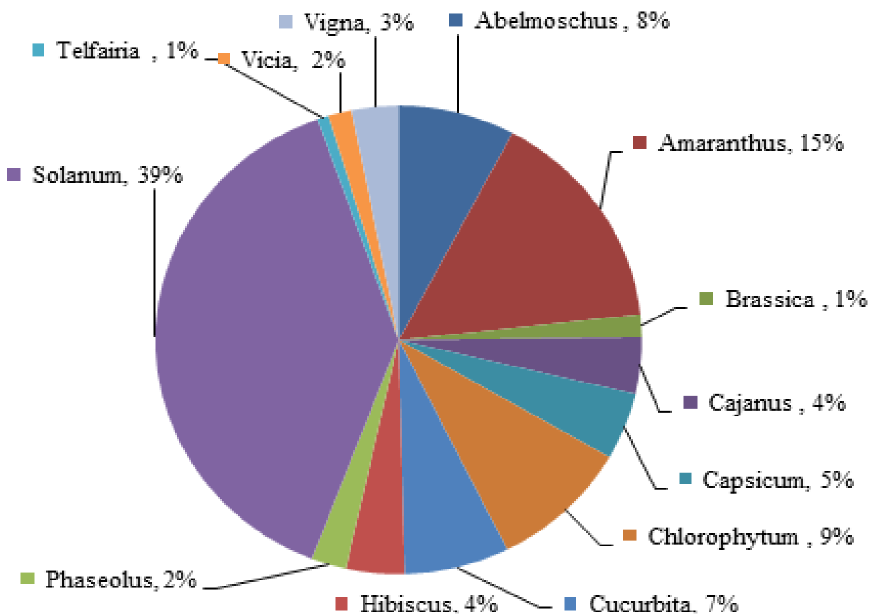

Figure 3. Overall abundance of AIVS genera in Uganda in 2015.

Table 2. Regional distribution of AIVS genera in Uganda in 2015.

Genus	Family	Number and proportion of samples per region								Total	
		Central		Eastern		Northern		Western			
		#	%	#	%	#	%	#	%	#	%
Abelmoschus	Malvaceae	0	0.0	0	0.0	10	7.8	0	0.0	10	7.8
Amaranthus	Amaranthaceae	4	3.1	8	6.2	4	3.1	4	3.1	20	15.5
Brassica	Brassicaceae	0	0.0	0	0.0	2	1.6	0	0.0	2	1.6
Cajanus	Fabaceae	2	1.6	1	0.8	2	1.6	0	0.0	5	3.9
Capsicum	Solanaceae	0	0.0	2	1.6	0	0.0	4	3.1	6	4.7
Chlorophytum	Asparagaceae	1	0.8	7	5.4	4	3.1	0	0.0	12	9.3
Cucurbita	Cucurbitaceae	0	0.0	4	3.1	4	3.1	1	0.8	9	7.0
Hibiscus	Malvaceae	0	0.0	0	0.0	5	3.9	0	0.0	5	3.9
Phaseolus	Fabaceae	2	1.6	0	0.0	1	0.8	0	0.0	3	2.3
Solanum	Solanaceae	8	6.2	13	10.1	4	3.1	25	19.4	50	38.8
Telfairia	Cucurbitaceae	1	0.8	0	0.0	0	0.0	0	0.0	1	0.8
Vicia	Fabaceae	1	0.8	0	0.0	1	0.8	0	0.0	2	1.6
Vigna	Fabaceae	1	0.8	2	1.6	1	0.8	0	0.0	4	3.1
Total		20	15.5	37	28.7	38	29.5	34	26.4	129	100

#, Number of samples; %, Percentage.

Amaranthus dubius, *Chlorophytum cosmosus*, *A. esculentus* and *Solanum anguivi* were the five most prevalent at 12.4, 9.3, 9.3, 7.8 and 7.8%, respectively. Other relatively abundant AIVS encountered were *Cucurbita pepo*, *Solanum nigrum*, *Solanum lycopersicum varcerasiforme*, *Capsicum annuum* and *Solanum pimpinellifolium* (Table 3). In the Central, Eastern, Northern and Western regions, the most abundant species were *A. dubius*, *Chlorophytum comosum*, *A. esculentus* and *S. aethiopicum*, respectively.

DISCUSSION

Having encountered only 23 species during the survey, it indicates a continuous loss in biodiversity of AIVS of

Table 3. Regional distribution of African indigenous vegetable species in Uganda in 2015.

Species	Family	Number and proportion of samples per region								Total	
		Central		Eastern		Northern		Western			
		#	%	#	%	#	%	#	%	#	%
Solanum aethiopicum	Solanaceae	2	1.6	3	2.3	1	0.8	10	7.8	16	12.4
Amaranthus dubius	Amaranthaceae	3	2.3	3	2.3	2	1.6	4	3.1	12	9.3
Chlorophytum comosum	Asparagaceae	1	0.8	7	5.4	4	3.1	0	0.0	12	9.3
Abelmoschus esculentus	Malvaceae	0	0.0	0	0.0	10	7.8	0	0.0	10	7.8
Solanum anguivi	Solanaceae	2	1.6	2	1.6	0	0.0	6	4.7	10	7.8
Cucurbita pepo	Cucurbitaceae	0	0.0	4	3.1	4	3.1	1	0.8	9	7.0
Solanum nigrum	Solanaceae	1	0.8	4	3.1	0	0.0	4	3.1	9	7.0
Solanum lycopersicum var. cerasiforme	Solanaceae	1	0.8	1	0.8	0	0.0	5	3.9	7	5.4
Capsicum annuum	Solanaceae	0	0.0	2	1.6	0	0.0	4	3.1	6	4.7
Solanum pimpinellifolium	Solanaceae	2	1.6	3	2.3	1	0.8	0	0.0	6	4.7
Amaranthus cruentus	Amaranthaceae	1	0.8	3	2.3	1	0.8	0	0.0	5	3.9
Cajanus cajan	Fabaceae	2	1.6	1	0.8	2	1.6	0	0.0	5	3.9
Hibiscus sabdariffa	Malvaceae	0	0.0	0	0.0	5	3.9	0	0.0	5	3.9
Phaseolus lunatus	Fabaceae	2	1.6	0	0.0	1	0.8	0	0.0	3	2.3
Amaranthus viridis	Amaranthaceae	0	0.0	1	0.8	1	0.8	0	0.0	2	1.6
Brassica oleracea var. acephala	Brassicaceae	0	0.0	0	0.0	2	1.6	0	0.0	2	1.6
Vicia faba	Fabaceae	1	0.8	0	0.0	1	0.8	0	0.0	2	1.6
Vigna unguiculata	Fabaceae	0	0.0	2	1.6	0	0.0	0	0.0	2	1.6
Solanum melongena	Solanaceae	0	0.0	0	0.0	2	1.6	0	0.0	2	1.6
Amaranthus spinosus	Amaranthaceae	0	0.0	1	0.8	0	0.0	0	0.0	1	0.8
Telfairia pedata	Cucurbitaceae	1	0.8	0	0.0	0	0.0	0	0.0	1	0.8
Vigna radiata	Fabaceae	0	0.0	0	0.0	1	0.8	0	0.0	1	0.8
Vigna subterranea	Fabaceae	1	0.8	0	0.0	0	0.0	0	0.0	1	0.8
Total		20	15.5	37	28.7	38	29.5	34	26.4	129	100

#, Number of samples; %, Percentage.

86.4% since 1989. A survey conducted in 1989 had reported 169 species of traditional vegetables; eight years later, the biodiversity report had reduced to 34 species representing a 79% loss (Alexandratos and Bruinsma, 2012; NEMA, 2009; Stone et al., 2011). The common causes of the biodiversity loss are thought to be civil wars (Alexandratos et al., 2012; FAO, 2013; Von Grebmer et al., 2015), human settlement, bush fires and prolonged drought (FAO, 2013; Kamga et al., 2016; NEMA, 2009; Pincus, 2015; Von Grebmer et al., 2015). The low species number encountered can also be attributed to the limited coverage of the different agro-ecologies during the survey as a result of limited research funding. It has been severally pointed out that inadequate funding is one of the bottlenecks that limit the extent of surveillance for species abundance, germplasm conservation, crop improvement and promotion of the AIVS utilization in Uganda (Abukutsa-Onyango, 2014; Alexandratos et al., 2012; Cernansky, 2015).

High abundance of *S. aethiopicum*, *A. dubius*, *C. cosmosus*, *A. esculentus* and *S. anguivi* emphasizes the importance of these species across regions in Uganda. Pincus (2015) and Cernansky (2015) held that some of the traditional vegetable species have a higher commercial value than coffee in urban/peri-urban areas. According to FAO (2013), Ebert (2014) and Alexandratos and Bruinsma (2012), indigenous vegetables are indispensable sources of both food and income; in addition to their medicinal value (Ayaz et al., 2015; Bationo-Kando et al., 2015; Bisamaza and Banadda, 2017; Chinedu et al., 2011; Ebert, 2014; Omulo, 2016; Pincus, 2015; Von Grebmer et al., 2015). Different agro-ecological zones however, tend to favor adaptation of specific traditional vegetables (Alexandratos and Bruinsma, 2012; Pincus, 2015; Stone et al., 2011). The other reasons for differences in abundance of difference species include the traditional norms and food preference by specific communities (Ebert, 2014; Omulo, 2016; Pincus, 2015). For instance *A. esculentus* is a common leafy vegetable in food preparation in Northern Uganda (Pincus, 2015). Similarly, *S. aethiopicum* ‘Shum group” and its wild progenitor *S. anguivi* are very prevalent in the Central and Western Uganda (Bisamaza and Banadda, 2017; FAO, 2013; Pincus, 2015).

Conclusion

Three families namely Solanaceae, Amaranthaceae and Malvaceae constituted the five most abundant species out of 23 species encountered. The five species observed to be most important include; *S. aethiopicum* (Solanaceae), *A. dubius* (Amaranthaceae), *C. cosmosus*, *A. esculentus* (Malvaceae) and *S. anguivi* (Solanaceae); most of which were the indigenous type except *A. dubius*. There is also a possible decline in the number of AIVS in Uganda based on the low number of species encountered.

The low species number encountered can either be due to the limited courage during the survey as a result of inadequate funding; but because it was a purpose sampling, serious other constraints such as drought over the years could have led to a biodiversity loss. Further still, it is notable that majority of the species encountered during the survey were indigenous type rather than the introduced ones, showing a growing interest for the former than the latter among farmers across regions in Uganda. It is recommended that efforts are devoted towards regular abundance surveys and increased conservation and utilization of indigenous vegetables that demonstrate potential for wide-scale adaptability across regions in Uganda. The conservation and genetic improvement efforts could avert consequences of biodiversity loss of the AIVS that arise from limited research attention.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abukutsa-Onyango M (2014). Strategic repositioning African indigenous vegetables and fruits with nutrition, economic and climate change resilience potential. In *Novel Plant Bioresources* (Gurib-Fakim A. (Eds). London: John Wiley and Sons, pp. 361-369.

Adeniji OT, Kusolwa PM, Reuben S (2012). Genetic diversity among accessions of *Solanum aethiopicum* L. groups based on morpho-agronomic traits. Plant Genet. Resour. 10(03):177-185.

Agoreyo BO, Obansa ES, Obanor EO (2012). Comparative nutritional and phytochemical analyses of two varieties of *Solanum melongena*. Sci. World J. *7*(1):5-8.

Alexandratos N, Bruinsma J (2012). World agriculture towards 2030/2050: the 2012 revision. ESA Working paper Rome, FAO. Retrieved from http://large.stanford.edu/courses/2014/ph240/yuan2/docs/ap106e.pdf

Ayaz FA, Colak N, Topuz M, Tarkowski P, Jaworek P, Seiler G, Inceer H (2015). Comparison of Nutrient Content in Fruit of Commercial Cultivars of Eggplant (*Solanum melongena* L.). Pol. J. Food Nutr. Sci. 65(4):251-260.

Bationo-Kando P, Sawadogo B, Nanema K, Kiebre Z, Sawadogo N, Traore R, Sawadogo M, Zongo JD (2015). Characterization of Solanum aethiopicum (Kumba group) in Bukina Faso. Int. J. Sci. Nat. 6(2):169-176.

Bisamaza M, Banadda N (2017). Solar drying and sun drying as processing techniques to enhance the availability of selected African indigenous vegetables, Solanum aethiopicum and Amaranthus lividus for nutrition and food security in Uganda. Afr. J. Food Sci. Technol. 8(1):001-006.

Borràs D, Plazas M, Andújar I, Gramazio P, Herraiz FJ, Prohens J, Vilanova S (2015). Molecular Characterization of Scarlet and Gboma Eggplants Based on Single Nucleotide Polymorphisms. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture 72:2.

Cernansky R (2015). Super vegetables. Nature 522(7555):146.

Chinedu SN, Olasumbo AC, Eboji OK, Emiloju OC, Arinola OK, Dania DI (2011). Proximate and phytochemical analyses of *Solanum aethiopicum* L. and *Solanum macrocarpon* L. fruits. Res. J. Chem. Sci. 1(3):63-71.

Ebert A (2014). Potential of Underutilized Traditional Vegetables and Legume Crops to Contribute to Food and Nutritional Security, Income and More Sustainable Production Systems. Sustainability 6(1):319-335.

FAO (2013). FAO statistical yearbook 2013: World food and agriculture. Rome: Food and Agriculture Organization of the United Nations. http://www.fao.org/docrep/018/i3107e/i3107e00.htm

Kamga R, Salibo S, Abdou T, Yakubu BI, Ousmane N (2016). Assessment of traditional African vegetable production in Burkina Faso. J. Agric. Extension Rural Dev. 8(8):141-150.

Kouassi A, Béli-Sika E, Tian-Bi T, Alla-N'Nan O, Kouassi A, N'Zi JC, N'Guetta AS, Tio-Tour B (2014). Identification of Three Distinct Eggplant Subgroups within the Solanum aethiopicum Gilo Group from Côte d'Ivoire by Morpho-Agronomic Characterization. Agriculture 4(4):260-273.

NEMA (2009). Fourth National Report to the convention on biological diversity (No. 4) (p. 145). National Environment Management Authority (NEMA), Ministry of Water and Mineral Development.

Ojiewo C, Tenkouano A, Hughes J, Keatinge JDH (2013). Diversifying diets: using indigenous vegetables to improve profitability, nutrition and health in Africa. Diversifying Food and Diets P 291.

Omulo D (2016). Value addition on traditional vegetables: an impact assessment on women farmers in Lugari, Kenya. University of Nairobi, Nairobi, Kenya.

Pincus LM (2015). Increasing indigenous vegetable yield and nutritional quality through traditionally-and scientifically-informed soil fertility management. University of California, Davis.

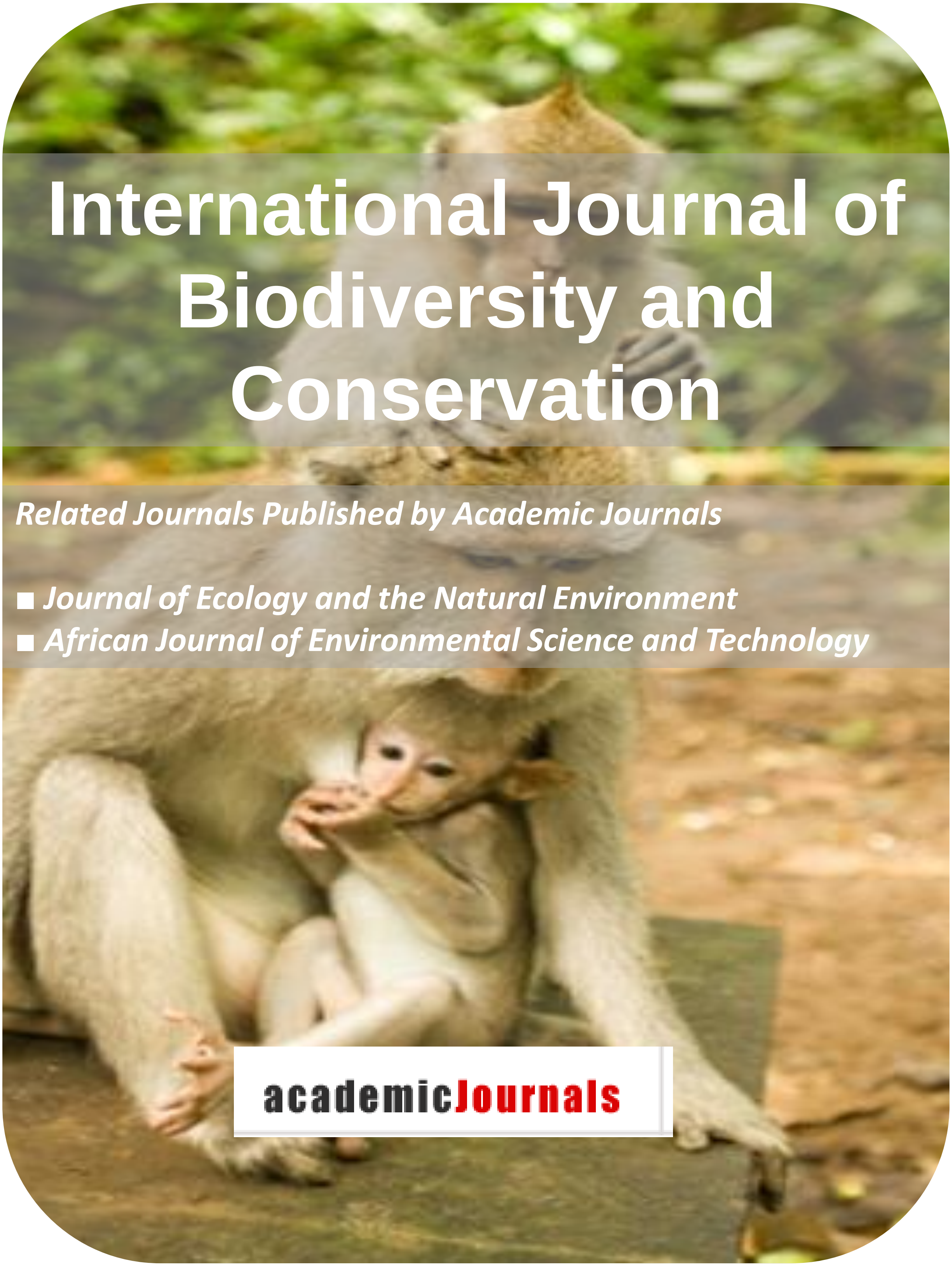
Prohens J, Whitaker BD, Plazas M, Vilanova S, Hurtado M, Blasco M, Gramazio P, Stommel JR (2013). Genetic diversity in morphological characters and phenolic acids content resulting from an interspecific cross between eggplant, *Solanum melongena* , and its wild ancestor (*S. incanum*): Morphology and phenolics in an interspecific family in eggplant. Ann. Appl. Biol. 162(2):242-257.

Stone A, Massey A, Theobald M, Styslinger M, Kane D, Kandy D, Tung A , Adekoya A , Madan J, Davert E (2011). Africa's Indigenous Crops.

State of the World-Innovations that Nourish the Planet. The Worldwatch Institute. Washington, 8 p.

Syfert MM, Castaneda-Alvarez NP, Khoury CK, Sa rkinen T, Sosa CC, Achicanoy HA, Bernau V, Prohens J, Daunay MC, Knapp S (2016). Crop wild relatives of the brinjal eggplant (Solanum melongena): Poorly represented in genebanks and many species at risk of extinction. Am. J. Bot. 103(4):635-651.

Von Grebmer K, Bernstein J, de Waal A, Prasai N, Yin S, Yohannes Y (2015). 2015 Global hunger index: Armed conflict and the challenge of hunger. International Food Policy Research Institute.



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