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Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Invasive alien flora of Jhabua district, Madhya Pradesh, India

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The present study deals with comprehensive list and status of invasive plant species in Jhabua district of Madhya Pradesh along with their life form, nativity, uses, habitat, categories and mode of introduction. A total of 102 invasive alien plant species belonging to 80 genera under 39 families were recorded from the study area. The analysis of invasive species reveals that 16 species have been introduced intentionally, while the remaining species established were unintentionally through trade. Sixty four aliens have their origin in Tropical America as compared to 14 species in African continent. About 23 species of alien plants reached the study area from such far off places. A better planning is needed for early detection to control and report infestation of spread of new and naturalised weed to be monitored.

Key words: Invasive alien, Jhabua district, Madhya Pradesh.

INTRODUCTION

The International Union for Conservation of Nature and Natural Resources (IUCN) defines “alien invasive species” as an alien species which becomes established in natural or seminatural ecosystems or habitat as agent of change and threatens native biological diversity. Biological invasions of alien plants present one of the most serious threats to long-term maintenance of ecosystem health and biodiversity (Westman, 1990; Tyser and Key, 1988) and pose a major threat to indigenous biological diversity. Invasive alien plants have caused extensive economic and ecological damage throughout the world. Therefore, the effects of biological invasions are increasingly being recognized for their role in degradation of biological diversity worldwide (Usher et al., 1988; D’Antonio and Vitousek, 1992). Biological invasion may be considered as a form of biological pollution and the significant component of anthropogenic changes leading to extinction of native species (IUCN). The ecological approach to plant invasion has been mostly based on biological and ecological features promoting the invasion success of particular species (Newsome and Noble, 1986; Rejmánek, 1995), the character and invisibility of invaded communities (Rejmánek, 1989). Recently, both approaches are treated as complementary (Lodge, 1993;

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Hobbs and Huenneke, 1992). The phytogeographical and floristic approaches are important for research on alien plants (McNeely et al., 2001). A number of workers have studied and provided catalogues of the invasive alien plant species in different parts of the world (Drake et al., 1989; Williamson, 1996; Carey et al., 1996; Pyšek et al., 2012). Alien plants have various effects on the environment and economy of non-native areas, many of the exotic plants are of economic benefit and some have severe negative impacts. Some alien species, often cultivated, may provide food, medicine, fuel or fodder to local communities (Kull et al., 2007; Roder et al., 2007) and some of them are responsible for endangerment and extinction of native species and has negative impact on crop production, forest regeneration, livestock grazing and on human health (Sharma et al., 2005; Kohli et al., 2006). It is estimated that as many as 50% of invasive species in general can be classified as ecologically harmful, based on their actual impacts (Richardson et al., 2000).

Over the last many decades, a number of invasive species have been introduced in India from their native areas either accidentally or deliberately as fodder crops or ornamentals. It is fueled rapidly during the last half-century as the globalisation of trade and industry has resulted in increased mobility of people and goods, and the associated transport of plants, animals and micro-organisms around the world. Due to increasing trade and transcontinental transport, the floras of Indian subcontinent have a number of alien species from various parts of the world as evident from the studies made at different parts in India, namely, Upper Gangetic Plain (Raizada, 1935, 1936), Kodaikanal and Palani Hills (Matthew, 1969), Kashmir Himalaya (Singh and Misri, 1974; Singh and Kachroo, 1983), Ranchi (Maheswari and Paul, 1975), Gangtok (Hajra and Das, 1982), Allahabad (Sharma, 1984), Melghat Tiger Reserve (Sawarker, 1984), Rajasthan (Pandey and Parmar, 1994), South Gujarat (Kshirsagar, 2005), Doon Valley (Negi and Hajra, 2007), Indian Himalayan Region (Sekar, 2012), Johrat, Assam (Das and Duarah, 2013) and North Eastern Uttar Pradesh (Srivastava et al., 2014). Likewise, the western Madhya Pradesh of India is also invaded by a variety of Invasive alien plants. Without realizing the consequences, they have been introduced into the study area knowingly or unknowingly. In Western Madhya Pradesh of Jhabua district, comprehensive studies on invasive species and plant invasions are still missing. Studies on sacred grove and ethnobotany in Jhabua district were done (Jain et al., 2011; Wagh and Jain, 2010, 2013, 2014). In view of this, the present study attempted to focus on document of the invasive alien species in the flora of Jhabua district. This listed invasive exotic species will serve as basic information for future research towards the conservation of endemic and natural forest vegetation of Madhya Pradesh.

Study site

Jhabua is the district head-quarter, situated in western part of Madhya Pradesh and situated at 22' 47 N latitude and 71' 35 E longitude at an average altitude of 428 m above mean sea level (Figure 1). Total area of the district is 6,792 sq. km. The Total population of the district as per 2001 census is 13, 94,345. Most of the village habitants of Jhabua belong to tribal communities like *Bheel, Bhilala* and *Pataya*. Out of these tribes *Bheel* and *Bhilala* stand high in strength, scattered in most of the villages of the district. The *Bhil* tribe is one of the most important and the third largest tribe of India. In district, about 28% of the area is covered with forest whose total area is 1900 sq. km.

MATERIALS AND METHODS

Intensive floristic surveys were undertaken during 2008 - 2013 in Jhabua district in the manner that each locality could be studied in each season of the year. Periodic collection of plants was made from each locality to collect the invasive plant species. The specimens were dried and pressed in the field and taken to the laboratory and herbarium was prepared according to the customary methods (Lawrence, 1951). These plant specimens were critically studied and identified with the help of various floras and published literature (Hooker, 1822, 1883; Cooke, 1901, 1908; Duthie, 1903, 1929; Gamble and Fisher, 1957; Kaushik, 1973; Oommachan, 1977; Kaushik, 1983; Maheshwari, 1963; Randhava, 1983; Deshpande and Singh, 1986; Verma et al., 1993; Kumar and Lal, 1995, 1998; Khanna and Kumar, 2000, 2006; Khanna et al., 2001). The identification was also made by referring some authentic publications and deposited in the herbarium of S.K. Jain Institute of Ethnobiology, Jiwaji University, Gwalior. Several extensive reviews were studied on invasive plant species that are available (Mooney and Drake, 1987; D'Antonio and Vitousek, 1992; Jenkins, 1999; Mooney and Hobbs, 2000; Elton, 2000; Cowie, 2001; Wasson, 2003). The website http://www.isws.in/invasive-plants-of-india.php (Reddy et al., 2008) was also searched for information on the origin and nativity of these invaders. Some information pertaining to the nativity of the species in India has been extracted from: Raghubanshi et al. (2005), Sujay et al. (2010), Singh (1976) and Sinha (1976). Invasive alien species occurring in this region were compiled based on the field observation, literature survey and discussion with local people. They were divided into three categories: naturalized, interfering and noxious. Self replacing plant populations by recruitment through seeds/ramets and capable of independent growth were categorized as naturalized. Alien and native plants which impacted agriculture adversely especially on the disturbed sites were taken as noxious. The adverse impact of noxious species was in the form of competition for space with tillage or forage crops and harbouring of pests or disease vectors, harmful to crops/native species. In addition to efficient vegetative mode of propagation, the seeds of these species are mostly wind distributed and may remain viable for several years. The species which were neither injurious nor noxious but caused profuse interference and hindrance to the growth of crop/native species over a large area by virtue of their vast numbers were taken as interfering. The invasive species are enumerated alphabetically with voucher specimen number and family in parenthesis followed by local name, life form, nativity, uses, habitat, categories and mode of introduction.

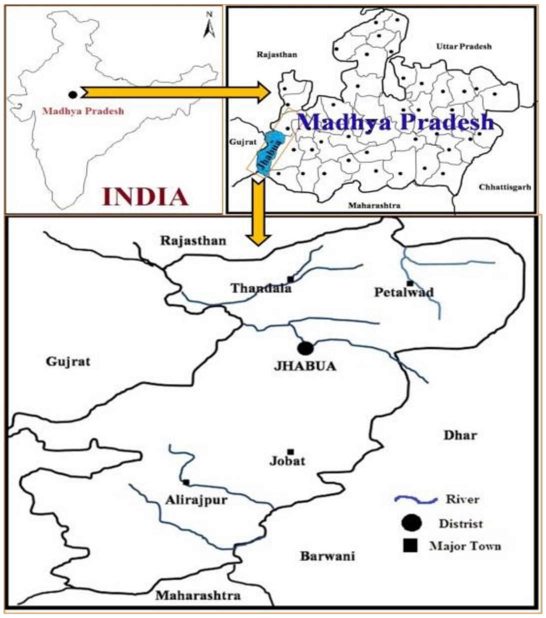

Figure 1. Map of Jhabua District of Madhya Pradesh, India.

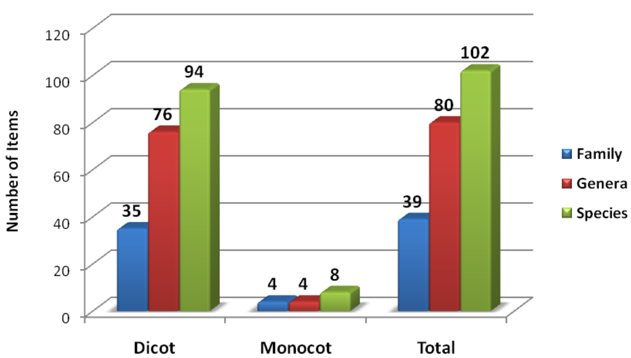

Figure 2. Status of genera, species and family of Invasive alien plant species in Jhabua ditrict.

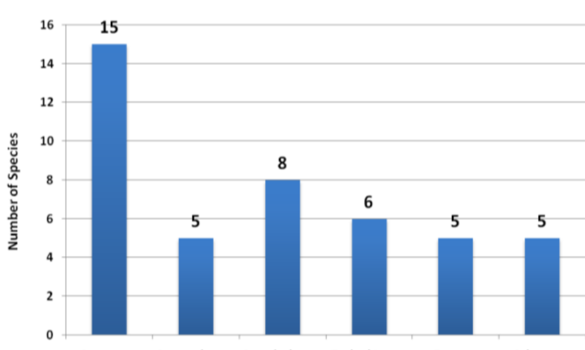

Figure 3. Dominant families of invasive alien plant species in Jhabua ditrict.

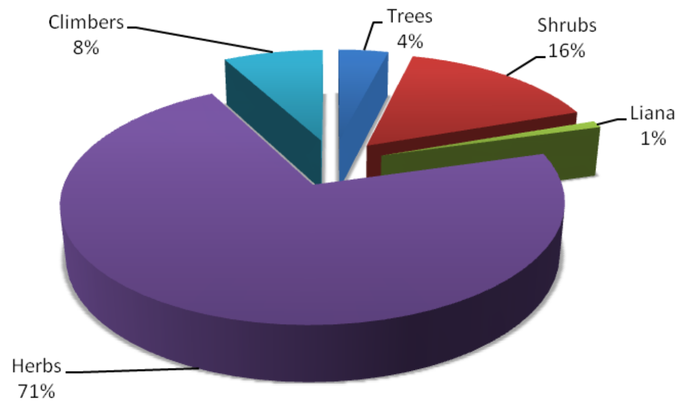

Figure 4. Life form of invasive alien plant species in Jhabua ditrict.

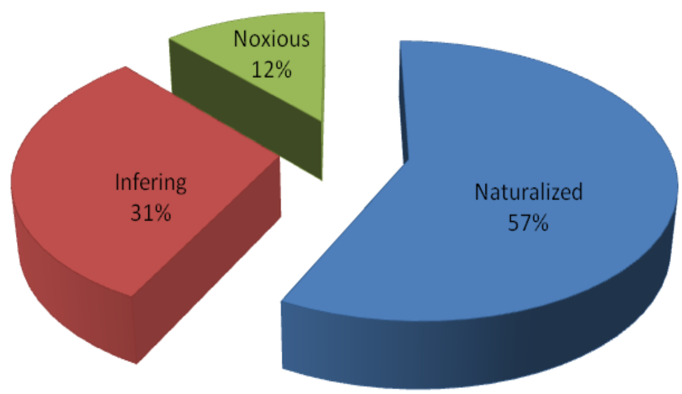

Figure 5. Status of invasive alien plant species in Jhabua ditrict.

RESULTS AND DISCUSSION

A total of 102 species of invasive aliens plants species from Jhabua district of Madhya Pradesh have been documented. These 102 alien species belonged to 80 genera under 39 families. The number of dicot alien species was 94, under 76 genera and 35 families. On the other hand, there were only 8 species of monocot aliens distributed among 4 genera under 4 families (Arecaceae, Liliaceae, Pontederiaceae and Poaceae) (Figure 2). Of 39 families having alien species, Asteraceae was the most dominant (15 species) followed by Convolvulaceae (8), Amaranthaceae and Euphorbiaceae (5 species each), Poaceae (5) and Solanaceae (5) (Figure 3). Of these aliens, 12 species were judged as noxious, 32 species as interfering, and 58 as naturalized species (Figure 4). Habit wise analysis shows that 71% of species are herbs, 16% are shrubs, 8% climbers, 4% are trees and 1% liana (Figure 5). The six dominant families contributed 45% of the invasive alien flora of wild vegetation of Jhabua district of western Madhya Pradesh.

The alien species amounted to 4.60% of the total 2214 wild plant species of the Madhya Pradesh state. 64 aliens have their origin in Tropical America as compared to 14 species in African continent. About 23 species of alien plants reached the study area from such far off places as Afghanistan, Brazil, Europe, Madagascar, Mediterranean, Mexico, Peru, South-West Asia Temperate South America, Tropical West Asia and West Indies. The herbaceous elements predominated the regional alien flora.

In the present study, however, only the wild invasive plant species were considered. Many species, recorded as invader of Jhabua ditrict, are common to whole India (Reddy, 2008) and also with whole of the Uttar Pradesh (Singh et al., 2010), Indian Himalayan Region (Sekar, 2012), Johrat (Das and Duarah, 2013) and North Eastern Uttar Pradesh (Srivastava et al., 2014). Among the invasive species of Jhabua district, 63.36% are native to American continent. Other such studies vary slightly in percent share of tropical American nativity. While Das and Duarah (2013) reported 88% invaders from American nativity. Singh et al. (2010) reported 73% of invasive plant species of Uttar Pradesh, for Indian Himalayan region, Sekar (2012) also noticed 73% invaders, for North Eastern Uttar Pradesh (Srivastava et al., 2014) noticed 66% invasive alien species and Reddy (2008) noticed 58% of the invasive flora of India to be natives of American continent.

Alien species have been classified into naturalized and noxious species by various workers (Richardson et al., 2000; Wu et al., 2004; Huang et al., 2009). Of the total alien plant species in Jhabua district, 12% species were judged as noxious, 31% are intergering and 57% as naturalised. Our field observation and discussion with local people indicate that there are 12 most noxious invasive plant species in this region, namely, *Ageratum conyzoides, Antigonon leptopus, Argemone mexicana, Cassia tora, Datura innoxia, Echinochloa crus-galli, Lantana camara, Lagascea mollis, Leucaena leucocephala, Parthenium hysterophorus, Opuntia elatior* and *Xanthium strumarium.* Some species such as *Ageratum conyzoides, L. camara* and *P. hysterophorus* are harmful to native species (Singh et al., 2010; Tripathi and Shukla, 2007; Dogra et al., 2009). Further, some of these species are known to be highly allergic, causing diseases in human beings (Saxena, 1991; Tripathi, 1999). Since they are rarely palatable, their dominance drastically reduces the number of grazers by way of reducing the carrying capacity of the pasture and wasteland (Sawarker, 1984). *D. innoxia* and *Datura stramonium* are serious threat to the native species of the region and are known to cause delay in seedling growth of neighbouring plants (Sood et al., 2011). *L. leucocephala* alters the natural growth of native plants because not only it obstructs plenty of sunlight to reach surface layer but also its allelopathic exudates cause retardation in seedling growth of neighbouring plants (Chou, 1980).

Many invasive species tend to respond to temporarily nutrient enriched soil substrata and grow quickly cover the gaps in disturbed forests. They can destroy arable soil, negatively affect the growth of orchard, and could also supplant grasses in pasture, excreting a toxic volatile that prevents grazing (Saxena, 1991). The noxious plants are present in agricultural field as well as in the disturbed sites, their overgrowth results into the yield of the crop and so as economy of the farmers. The interfering invasive plants creat a diturbace and hinderance in agriculture field and in the forest undergrowth. Their number is increasing very fastly by replacing the native flora. This is the alarming condition for the conservation of local floristic diversity.

The herbaceous invasive plant species were recorded as the dominant invasive flora (71%) of Jhabua district. The greater viability and tolerance to harsh conditions could result in the preponderance of herbs across the region. Invasive species of Asteraceae exhibited a much higher reproductive capacity than those of other families. This high reproductive potential is achieved by partitioning of reproductive capital into a large number of propagules that are minute, light and wind dispersed (Saxena and Ramakrishnan, 1982). Various other workers have also reported the dominance of Asteraceae among invasive alien species. Rao and Murugan (2006) found that the Asteraceae is dominating family in alien flora of India, in Uttar Pradesh (Singh et al., 2010), in Indian Himalayan region (Sekar, 2012), in Johrat, Assam Das and Duarah (2013) and in North eastern Uttar Pradesh (Srivastava et al., 2014). Conolvulaceae is the second largest family in the study area because the area contents most of the open and thickets types of forest and this is the congeal habitat for the growth of climbers including the members of the family convolvulaceae. Monocots are present in the wetland or marshy type of habitat but the present area is under semi-arid zones of India therefore, there represenatation is least in the study area.

Only 16 species namely, *Ageratum conyzoides*, *Catharanthus pusillus*, *Celosia argentea*, *Chenopodium album*, *Duranta repens, Eichhornia crassipes*, *Impatiens balsamina*, *Ipomoea eriocarpa*, *Ipomoea quamoclit*, *Lantana camera*, *Leucena leucocephala*, *Mirabilis jalapa*, *Passiflora foetida*, *Portulaca oleracea, Prosopis julliflora* and *Synadenium grantii* are seem to have been introduced deliberately; the rest of them unintentionally through trade exchange including grain import. A total of 15 different geographic regions in terms of nativity are recorded in the present study. About 54.45% of invasive species were most abundant in wastelands, while cultivated fields, road sides, river beds, forest/forest edges, aquatic, parasites were favored by 19, 18, 5, 7, 2 and 2% respectively. Many of the invasive species are of economic benefit also about 62 species listed in Table 1 are reported to be used by locals for medicinal purposes.

Table 1. List of Invasive plant species found in Jhabua district of Madhya Pradesh, India.

Botanical name and family	Local name	Life form	Nativity	Uses	Habitat	Categories	Mode of introduction
Acanthospermum hispidum DC. (JBA-483) Asteraceae	Chota Gokhru	Herb	Brazil	M	W	Naturalized	Ui
Ageratum conyzoides L. (JBA-71) Asteraceae	Jangali Gobi	Herb	Tropical America	M	W	Noxious	O
Alternanthera sessilis (L.) R.Br. *ex* DC. (JBA-42) Amaranthaceae	Guroo sag	Herb	Tropical America	M	RB	Naturalized	Ui
Alternanthera pungens Kunth (JBA-635) Amaranthaceae	Guroo sag	Herb	Tropical America	M, V	W	Naturalized	Ui
Amaranthus spinosus L. (JBA-319) Amaranthaceae	Chaulai	Herb	Tropical America	M, V	CF	Naturalized	Ui
Anagallis arvensis L.(JBA-41) Primulaceae	Phooli	Herb	Europe	M	CF	Naturalized	Ui
Antigonon leptopus Hook. & Arnott (JBA - 610) Polygonaceae		Climber	Tropical America	O	AR	Noxious	Ui
Argemone mexicana L. (JBA - 210). Papaveraceae	Pili kateli	Herb	Tropical South America	M	W	Noxious	Ui
Asphodelus tenuifolius Cav. Liliaceae	Khod	Herb	Trop. America	M	A	Interfering	Ui
Blainvillea acmella (L.) Philipson (JBA-438) Asteraceae	Kanghi	Herb	Tropical America	Ch	W	Interfering	Ui
Blumea lacera (Burm.) *f.* DC. (JBA-335) Asteraceae	Burando	Herb	Tropical America	M	W	Interfering	Ui
Blumea obliqua (L.) Druc (JBA-336) Asteraceae	Burandi	Herb	Tropical America	Ch	W	Interfering	Ui
Borassus flabellifer L. (JBA - 555) Arecaceae	Tad	Tree	Tropical Africa	Hu, Br	W	Naturalized	Ui
Calotropis gigantea (L.) R.Br. (JBA-159) Apocynaceae	Aak	Shrub	Tropical Africa	M	W	Interfering	Ui
Calotropis procera (Aiton) R. Br. (JBA-157) Apocynaceae	Madar	Shrub	Tropical Africa	M	W	Interfering	Ui
Cassia absus L. (JBA - 16) Caesalpiniaceae	Chaksu	Herb	Tropical America	M	W	Naturalized	Ui
Cassia occidentalis L. (JBA - 257) Caesalpiniaceae	Kasundi	Shrub	Tropical South America	M	W	Naturalized	Ui
Cassia tora L. (JBA - 129) Caesalpiniaceae	Puadiya	Herb	Tropical South America	M	W	Noxious	Ui
Catharanthus pusillus (Murr.) G. Don (JBA-128) Apocynaceae	Ban sadabahar	Herb	Tropical America	Po	CF	Interfering	O
Celosia argentea L. (JBA-207) Amaranthaceae	Jangli murga	Herb	Tropical Africa	M, V	CF	Naturalized	Fd
Chenopodium album L. (JBA-340) Chenopodiaceae	Bathua	Herb	Europe	V	CF	Interfering	Fd
Chenopodium murale L. (JBA-388) Chenopodiaceae	Jangali bathua	Herb	Tropical America	V	CF, W	Naturalized	Ui
Chloris barbata Sw. (JBA - 378) Poaceae	Phuleri ghas	Herb	Tropical America	Fo	W	Naturalized	Ui
Cleome gynandra L. (JBA - 15) Capparidaceae	Safed hulhul	Herb	Tropical America	M,V	W	Naturalized	Ui
Cleome viscosa L. (JBA - 402) Capparidaceae	Pili hulhul	Herb	Tropical America	M	W	Naturalized	Ui

Uses: B- Basket making; Bf- Biomass fuel in rural area; Br- Broom; Ch- Presence of bioactive chemicals; Fi- Fibre; Fo- Fodder; Ft- Fruits edible; Hu-Hut; In- Insectiside; M- Medicinal; Nk- Not known; O- Ornamental; Po- Poisonous plant; Sa- Sacred Plant; Sm- Smoking; So- Social forestry, St-Secondary waste water treatment; T- Thatching; V- Vegetable; Habitat: W- Wastelands; CF-Cultivated fields; F- Forests; AR- Along roadside; A-Aquatic; P- Parasites; RB- River beds. Mode of introduction: Af- Agroforestry; Fd- Food; Fo- Fodder; O- Ornamental; Ui- Unintentional.

Table 1. Contd.

Botanical name and family	Local name	Life form	Nativity	Uses	Habitat	Categories	Mode of introduction
Convolvulus arvensis L. (JBA-516) Convolvulaceae	Shankpushpi	Herb	Europe	M	F, W	Naturalized	Ui
Corchorus tridens L. (JBA - 577) Tiliaceae	Rajan	Herb	Tropical Africa	V	AR, W	Naturalized	Ui
Corchorus trilocularis L. (JBA - 22) Tiliaceae	Rajanbhaji	Herb	Tropical Africa	V	W	Naturalized	Ui
Croton bonpalndianus Baill. (JBA-632) Euphorbiaceae	Bhangro	Herb	Temperate South America	Ch	W	Naturalized	Ui
Cryptostegia grandiflora R.Br. (JBA-452) Asclepiadaceae		Liana	Madagascar	O	CF	Interfering	Ui
Cuscuta chinensis Lam. (JBA-655) Cuscutaceae	Amarbel	Climber	Mediterranean	M	P	Interfering	Ui
Cuscuta reflexa Roxb. (JBA-21) Cuscutaceae	Amarvelo	Climber	Mediterranean	M	P	Interfering	Ui
Cynodon dactylon (L.) Pers. (JBA - 75) Poaceae	Dub	Herb	Africa	M, Fo	W	Naturalized	Ui
Datura innoxia Mill. (JBA-446) Solanaceae	Datura	Shrub	Tropical America	M	W	Noxious	Ui
Datura metel L. (JBA-515) Solanaceae	Kala Datura	Shrub	Tropical America	M	W	Interfering	Ui
Digera muricata (L.) Mart. (JBA-14) Amaranthaceae	Gol bhaji	Herb	South-West Asia	M	CF	Interfering	Ui
Duranta repens L. (JBA - 609) Verbenaceae	Pili heg	Shrub	America	O	CF	Naturalized	Af
Echinochloa crusgalli (L.) P. Beauv. (JBA - 267) Poaceae	Khas	Herb	Tropical South America	Fo	RB	Noxious	Ui
Echinops echinatus Roxb. (JBA-286) Asteraceae	Oontakato	Herb	Afghanistan	M	W	Naturalized	Ui
Eclipta prostrata (L.) L. (JBA-60) Asteraceae	Bhrigraj	Herb	Tropical America	M	AR	Naturalized	Ui
Eichhornia crassipes (Mart.) Solms (JBA - 538) Pontederiaceae	Jalkumbhi	Herb	Tropical America	St	A	Naturalized	O
Euphorbia heterophylla L. (JBA - 622) Euphorbiaceae	Dudhli	Herb	Tropical America	O	CF	Naturalized	Ui
Euphorbia hirta L. (JBA - 90) Euphorbiaceae	Kali dudhi	Herb	Tropical America	M	CF	Naturalized	Ui
Evolvulus nummularius (L.) L. (JBA-495) Convolvulaceae	Shankpushpi	Herb	Tropical America	Ch	W	Naturalized	Ui
Glossocardia bosvallea (L.*f.*) DC. (JBA-487) Asteraceae	Nakchikni	Herb	West Indies	Nk	W	Naturalized	Ui
Gomphrena celosioides Mart. (JBA-634) Amaranthaceae	Chota murga	Herb	Tropical America	Fo	CF	Naturalized	Ui
Hyptis suaveolens (L.) Poit. (JBA-104) Lamiaceae	Ban tulsa	Herb	Tropical America	M	AR	Interfering	Ui
Impatiens balsamina L. (JBA - 10) Balsaminaceae	Tiwadi	Herb	Tropical America	O	AR	Naturalized	O
Imperata cylindrica (L.) P. Beauv. var. major (Nees) Hubb. *ex* Hubb. & Vaughan (JBA - 394) Poaceae	Dabh	Herb	Tropical America	R	W	Naturalized	Ui
Indigofera linifolia (L. *f.*) Retz. (JBA - 144) Fabaceae	Torki	Herb	Tropical South America	M	AR	Naturalized	Ui

Table 1. Contd.

Botanical name and family	Local name	Life form	Nativity	Uses	Habitat	Categories	Mode of introduction
Indigofera linnaei Ali (JBA - 201) Fabaceae	Leel	Herb	Tropical South America	M	F	Naturalized	Ui
Indigofera trita L. *f.* (JBA - 08) Fabaceae		Shrub	Tropical Africa	Ch	F	Naturalized	Ui
Ipomoea carnea Jacq. (JBA-34) Convolvulaceae	Umarichata	Shrub	Tropical America	M	W	Interfering	Ui
Ipomoea eriocarpa R.Br. (JBA-167) Convolvulaceae		Herb	Tropical Africa	M	W	Interfering	O
Ipomoea hederifolia L. (JBA-598) Convolvulaceae	Lal bel	Climber	Tropical America	M	F	Interfering	Ui
Ipomoea nil (L.) Roth (JBA-420) Convolvulaceae	Nilari	Climber	North America	M	FE, W	Interfering	Ui
Ipomoea pestigridis L. (JBA-496) Convolvulaceae	Nali	Climber	Tropical East Africa	M	W	Interfering	Ui
Ipomoea quamoclit L. (JBA - 686) Convolvulaceae	Kamlata	Climber	Tropical America	M	W	Interfering	O
Jatropha curcas L. (JBA - 33) Euphorbiaceae	Ratanjot	Shrub	Tropical America	M, Fe, Sa	AR, CF	Naturalized	Ui
Jatropha gossypifolia L. (JBA - 52) Euphorbiaceae	Lal Ratanjyot	Shrub	Brazil	M	AR	Naturalized	Ui
Lagascea mollis Cav. (JBA-89) Asteraceae	Jangali jeera	Herb	Tropical Cent. America	M	AR, CF	Noxious	Ui
Lantana camara L (JBA-105) Verbenaceae	Jhai	Shrub	Tropical America	Bf	F	Noxious	O
Leonotis nepetifolia (L.) R. Br. (JBA-677) Lamiaceae	Lal gumda	Herb	Tropical Africa	M	W	Interfering	Ui
Leucaena leucocephala (Lamk.) de Wit (JBA - 119) Mimosaceae	Subabul	Tree	Tropical America	So, Fo	W	Noxious	Fo
Ludwigia octovalvis (Jacq.) Raven (JBA-147) Onagraceae	Jangali lawang	Herb	Tropical America	M	RB	Naturalized	Ui
Malachra capitata (L.) L. (JBA- 750) Malvaceae	Pili phulani	Herb	Trop. America	Fi, B	W	Interfering	Ui
Malvastrum coromandelianum (L.) Gar. Malvaceae	Kharenti	Herb	Tropical America	M, Fi	W	Naturalized	Ui
Martynia annua L. (JBA-77) Martyniaceae	Bicchua	Herb	Tropical America	M	W	Naturalized	Ui
Mimosa pudica L. (JBA-475) Mimosaceae	Chuimui	Herb	Brazil	M	F	Naturalized	Ui
Mirabilis jalapa L. (JBA - 59) Nyctaginaceae	Gulbas	Herb	Peru	O, Sa	W	Naturalized	O
Nicotiana plumbaginifolia Viv. (JBA-685) Solanaceae	Jangali tamakhu	Herb	Tropical America	Sm	W	Naturalized	Ui
Ocimum americanum L. (JBA-173) Lamiaceae	Jangali tulsi	Herb	Tropical America	Sa, In	W	Naturalized	Ui
Opuntia elatior Mill. Cactaceae	Nagphani	Shrub	Tropical America	M, Ft	AR, W	Noxious	Ui
Opuntia vulgaris Miller Cactaceae	Nagphani	Shrub	S. America	M, Ft	AR, W	Naturalized	Ui
Oxalis corniculata L. (JBA - 107) Oxalidaceae	Khatibuti	Herb	Europe	V	CF	Naturalized	Ui
Oxalis corymbosa DC.(JBA - 429) Oxalidaceae		Herb	South America	O, V	CF	Naturalized	Ui
Parthenium hysterophorus L. (JBA-383) Asteraceae	Gajarghas	Herb	Tropical North America	Nk	W	Noxious	Ui

Table 1. Contd.

Botanical name and family	Local name	Life form	Nativity	Uses	Habitat	Categories	Mode of introduction
Passiflora foetida L. (JBA-296) Passifloraceae	Rakhibel	Climber	Tropical South America	M	W	Interfering	O
Peperomia pellucida (L.) Kunth (JBA-633) Piperaceae		Herb	Tropical South America	V	AR	Naturalized	Ui
Peristrophe paniculata (Forssk.) Brummitt (JBA-25) Acanthaceae	Lal jeera	Herb	Tropical America	M	W	Interfering	Ui
Physalis minima L. (JBA-116) Solanaceae	Kanphuti	Herb	Tropical America	M, Ft	W	Naturalized	Ui
Portulaca oleracea L. (JBA - 428) Portulacaceae	Golbhaji	Herb	Tropical S. America	M, V	W	Naturalized	Fd
Prosopis juliflora (Swartz) DC. (JBA-26) Mimosacceae	Reuja	Tree	Mexico	Bf	W	Naturalized	Af
Ricinus communis L. (JBA - 57) Euphorbiaceae	Arandi	Tree	Africa	M, In	W, CF	Interfering	Ui
Ruellia tuberosa L. (JBA-638) Acanthaceae		Herb	Tropical America	Ch	AR	Naturalized	Ui
Saccharum spontaneum L. (JBA - 78) Poaceae	Kaans	Herb	TropicalWest Asia	M, B	RB	Interfering	Ui
Sesbania bispinosa (Jacq.) W. F. Wight Fabaceae	Daden	S	Trop. America	Fi	AR	Naturalized	Ui
Sida acuta Burm. *f.* (JBA - 490) Malvaceae	Atibala	Herb	Tropical America	M, Fi, Fo	W	Naturalized	Ui
Solanum nigrum L. Solanaceae	Makoi	H	Trop. America	M, Ft, Po	CF	Naturalized	Ui
Sonchus asper (L.) Hill. (JBA-155) Asteraceae	Jangali surajmukhi	Herb	Mediterranean	M	AR	Interfering	Ui
Sonchus oleraceus L. Asteraceae	Jangali surajmukhi	Herb	Mediterranean	M, V	RB	Interfering	Ui
Spermacoce hispida L. (JBA-458) Rubiaceae	Vasuka	Herb	Tropical America	M	AR	Interfering	Ui
Synadenium grantii Hook. *f.* (JBA - 506) Euphorbiaceae	Videshi ealaichi	Shrub	Tropical America	M	CF	Naturalized	O
Synedrella nodiflora (L.) Gaertn. (JBA-363) Asteraceae		Herb	West Indies	Nk	W, AR	Naturalized	Ui
Trema orientalis (L.) Blume (JBA - 498) Ulmaceae	Jivani	Shrub	Africa	M	W, AR	Naturalized	Ui
Tribulus terrestris L. (JBA - 27) Zygophyllaceae	Bhui Gokhru	Herb	Tropical America	M	W	Naturalized	Ui
Tridax procumbens L. (JBA-68) Asteraceae	Ghamra	Herb	Tropical Cent. America	M, V	CF	Naturalized	Ui
Triumfetta rhomboidea Jacq. (JBA - 342) Tiliaceae	Liptiya	Herb	Tropical America	M	W	Naturalized	Ui
Typha angustifolia Bory & Chaub.(JBA - 115) Typhaceae	Lav	Herb	Tropical America	T, Hu	RB	Naturalized	Ui
Urena lobata L. (JBA -564) Malvaceae	Bachita	Shrub	Tropical Africa	Fi	W	Interfering	Ui
Waltheria indica L. (JBA - 468) Sterculiaceae		Herb	Tropical America	M	F	Interfering	Ui
Xanthium strumarium L. (JBA-54) Asteraceae	Gokhru	Herb	Tropical America	M	AR	Noxious	Ui

Uses: B- Basket making; Bf- Biomass fuel in rural area; Br- Broom; Ch- Presence of bioactive chemicals; Fi- Fibre; Fo- Fodder; Ft- Fruits edible; Hu-Hut; In- Insecticide; M- Medicinal; Nk- Not known; O- Ornamental; Po- Poisonous plant; Sa- Sacred Plant; Sm- Smoking; So- Social forestry, St-Secondary waste water treatment; T- Thatching; V- Vegetable; Habitat: W- Wastelands; CF-Cultivated fields; F- Forests; AR- Along roadside; A-Aquatic; P- Parasites; RB- River beds. Mode of introduction: Af- Agroforestry; Fd- Food; Fo- Fodder; O- Ornamental; Ui- Unintentional.

The species namely, *L. leucocephala* is being effectively used for social forestry. The uses of three species are not known or even not used by locals. Many of the plant species such as *Amaranthus spinosus, Celosia argentea, Chenopodium album, Chenopodium murale, Cleome gynandra* etc are used as vegetable due to its nutritional potential. Many of the species are cultivated for various purposes such as food, medicine, fuel, fodder, religious, fodder by the local communities. But some of the species like *Echinochloa crus-galli*, *Lagascea mollis*, *L. camara* and *P. hysterophorus* are having high allelopathic potential and harmful to natural plant population (Singh et al., 2010).

Conclusion

Alien species are non-native or exotic organisms that occur outside their natural adapted ranges and have dispersal potential (McGeoch et al., 2010). These invasive species are widely distributed in all kinds of ecosystems throughout the world and include all categories of living organisms. Nevertheless, plants, mammals and insects comprise the most common types of invasive alien species in terrestrial environments (Raghubanshi et al., 2005). Many alien plant species support our farming and forestry systems in a big way. However, some of these aliens become invasive when they are introduced deliberately or unintentionally outside their natural habitats into new areas where they express the capability to establish, invade and out compete native species (Sujay et al., 2010). An important requirement for successful colonization of invaders is open habitat with reduced competition. Generally, the microsites created by grazing may be occupied by invader species (Singh, 1976; Sinha, 1976; Sawarker, 1984). The invaders usually dominate the highly disturbed and man-made landscapes. So far, no ready hand catalogue of invasive species is available for this region. The present catalogue of invasive exotic species is likely to serve as basic information for future research towards conservation of native plant species of the region.

The invasive species cause loss of biodiversity including species extinctions, and changes in hydrology and ecosystem function. Differences between native and exotic plant species in their requirements and modes of resource acquisition and consumption may cause a change in soil structure, its profile, decomposition, nutrient content of soil, moisture availability, etc. Invasive species are thus a serious hindrance to conservation and sustainable use of biodiversity, with significant undesirable impacts on the goods and services provided by ecosystems. Biological invasions now operate on a global scale and will undergo rapid increase in this century due to interaction with other changes such as increasing globalization of markets, rise in global trade, travel and tourism. For effective management of invasive species, knowledge about their ecology, morphology, phenology, reproductive biology, physiology and phytochemistry is essential (Raghubanshi et al., 2005). Monitoring of invasion can be done through qualitative approach like species inventory (seasonally) and quantitative approach using phytosociological methods and mapping using ground based methods (*via* map overlays or GPS), remotely-sensed images (aerial photos, high resolution multi-spectral digital data). Plant invasions in the new areas alter indigenous community composition, deplete species diversity, affect ecosystem process, and thus cause huge economic and ecological imbalance. A quick inventory and plant identification network are, therefore, needed for early detection and reporting of noxious and naturalized weeds in order to control the spread of invasive plant species. A better planning is needed for early detection and reporting of infestations of spread of new and naturalized weeds by creation of plant detection network in Jhabua district of Madhya Pradesh by establishing communication links between taxonomists, ecologists and land managers to monitor and control.

Conflict of interests

The authors did not declare any conflict of interest.

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Seasonal changes in small mammal assemblage in Kogyae Strict Nature Reserve, Ghana

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The small mammal community at Kogyae Strict Nature Reserve (KSNR) in the Ashanti Region of Ghana were studied in two habitats during the wet and dry seasons to investigate seasonal changes in species richness, abundance, composition and diversity. Ninety-six individuals belonging to nine species were recorded in 720 trap-nights, giving overall trap-success of 13.33%. Species richness (*Sr*), trap-success (*Ts*) and relative abundance (*Ra*) were higher (*Sr* = 6 species; *Ts* = 23.1%; *Ra* = 86.5%) in wooded grassland than forest (*Ra* = 4 species; *Ts* = 3.6%; *Ra* = 13.5%). However, species diversity was higher (Shannon-Wiener index *H*' = 1.157) in forest than in wooded grassland (*H*' = 1.089). *Mastomys erythroleucus* dominated in wooded grassland (68%) and *Hylomyscus alleni* in forest (53.8%). The species composition was unique for both habitats, with *Mus musculoides* being the only species common to both habitats. Seasonal changes in community assemblages were evident in both habitats, with species richness, diversity and abundance of the dominant species being highest in the wet seasons. Sex-ratio was unity in both habitats, and remained fairly constant throughout the rainy and dry seasons. Breeding activity was evident all-year-round for most species, but peaked in the rainy season. Our findings are consistent with that of other studies in Ghana and elsewhere in the African subregion, highlighting the importance of rainfall to the ecology of tropical small mammals.

Key words: African rain forest, community dynamics, habitat quality, live-trapping, rodents, tropical biodiversity, wildlife management.

INTRODUCTION

Identification of the factors that influence the distribution of species and temporal and spatial abundance, richness and composition of communities are of central importance in ecology, biogeography and biodiversity conservation. Knowledge of how natural environmental changes impact on organisms and how they in turn, respond to these changes can be used to forecast population trends, species turn-over and potential local extinctions (Soule et al., 2003; Manning and Edge, 2008). This in turn, can reveal subtle changes in environments and provide great insights into the threats facing biodiversity (Vos et al., 2000; Zahratka and Shenk, 2008), allowing for effective conservation planning and landscape management (Attum et al., 2008).

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Small mammals are important contributors of biodiversity and biomass of most natural and semi-natural ecosystems (Makundi et al., 2009; Habtamu and Bekele, 2012). They are the most diverse group of mammals, with considerable diversity in life-history, morphology and habitat associations. Rodents alone comprise over 40% of all mammalian fauna globally (Wilson and Reeder, 2005). Small mammals have complex effect on the structure, composition and functional diversity of their environment through various ecological interactions. For instance, by feeding on seeds, seedlings, fungal spores and insects, and serving as important sources of food for many medium-sized mammalian predators, raptors and snakes, small mammals maintain many food webs and ecosystem balance (Angelici and Luiselli, 2005). Some small mammals are also sensitive to even small changes in the environment (Malcom and Ray, 2000), as reflected in changes in their abundance, diversity and composition. Changes in the community structure of small rodents can therefore be used as surrogates for, and a quick and cost effective way of, measuring habitat quality or environmental disturbance (Avenant, 2011). Some small mammals are pests of agriculture and carriers of zoonotic diseases, causing significant economic losses and serious health implications (Habtamu and Bekele, 2012). Thus, the impacts of environmental change on small mammal populations have been the subject of intense research globally.

The abundance, diversity and community structure of small mammals are affected by several factors, including floristic composition, productivity, resource availability and microhabitat features such as available cover from predators (Nicolas and Colyn, 2003; Garratt et al., 2012). These factors in turn, are affected by climatic variability and disturbance regimes such as fire and habitat clearance (Jackson et al., 2009). In tropical and semi-arid regions, rainfall is often the most important driver of ecosystems' productivity (Coe et al., 1976). Small mammals therefore experience seasonal and inter-annual changes in abundance, composition and distribution tied to the amount and pattern of rainfall in space and time (Nicolas and Colyn, 2003).

In most tropical regions, natural habitats are being lost and degraded at alarming rates (FAO, 2007), posing serious threats to wildlife in general, and forest-specialist small mammals in particular, as these species require specific habitat structure and quality. The proliferation and mono-dominance of opportunistic species that are able to tolerate habitat modifications may further impoverish small mammal richness and diversity. It is feared that some tropical small mammal might be exterminated before they are discovered given the current rate of habitat loss in tropical regions. Therefore, it is of utmost necessity to conduct as many surveys as possible, particularly in unsurveyed areas that have experienced no or relatively less human modifications.

The composition of small mammal communities in many habitats and regions in Ghana is incompletely known. Knowledge of the effects of changing environments on this group of animals also is limited, despite recent efforts to bridge this knowledge gap (Yeboah, 1998; Decher and Bahian, 1999; Ryan and Attuquayefio, 2000; Decher and Abedi-Lartey, 2002; Attuquayefio and Wuver, 2003; Attuquayefio and Ryan, 2006; Barriere et al., 2009; Ofori et al., 2013a). A recent review of the status and challenge for conservation of small mammal assemblages of Ghana showed that 34 species of rodent (excluding squirrels, grasscutter), 14 species of shrews and one species of hedgehog have been recorded in the country between 1975 and 2014 (Ofori et al., unpublished). Most studies have been conducted in the southern part of the country. As yet, no small mammal study has been published from the forest-savanna transition zone and the two upper regions of Ghana (Ofori et al., unpublished).

In this study, we conducted small mammal trapping in two habitats: (i) forest and (ii) wooded grassland during the dry season and the minor and major rainy seasons to investigate seasonal changes in species richness, abundance, diversity and composition at the Kogyae Strict Nature Reserve in the Ashanti Region of Ghana.

MATERIALS AND METHODS

Study area

Kogyae Strict Nature Reserve (07° 12'N 01° 11'W), with an area of 386 km², is located in the forest/savanna transition zone in the Sekyere Central District of the Ashanti region. The climate is typical Transitional Woodland, with annual rainfall ranging between 1,200-1,300 mm (mean: 1,254 mm) and elevation of 120-130 m (WCMC, 2006). The area is bordered by the Afram River and riparian forest along its south-western boundary, as well as small pockets of dry forest and small rocky hills in the west. Much of the reserve has lost its status of "strict nature reserve", with an increasing number of farms encroaching from the south and east, as well as logging and hunting activities (Kyerematen et al., 2014). Common plant species included *Anogeissus leiocarpus, Ceiba pentandra, Cola gigantea, Khaya senegalensis, Milicia excelsa, Triplochiton scleroxylon*. *Daniellia oliveri, Ekebergia senegalensis* and *Manilkara multinervis.* Much of the grassland was replaced by the invasive *Chromolaena odorata*. Other tree species include *Afzelia africana, Cussonia arborea, Detarium microcarpum, Lannea barteri, Pterocarpus erinaceus, Terminalia laxiflora*. *Lophira lanceolata, Parkia biglobosa*, palms like *Borassus aethiopum* and figs (*Ficus platyphylla*).

Methods

Study site selection and trapping protocol

Small mammals were live-trapped in forest and wooded grassland, which form the major habitats in the study area. The wooded grassland is characterized by grasses and sedges, notably *Sporobolus pyramidalis, Vertiveria fulvibarbis, Panicum maximum, Andropogon gayanus* and *Heteropogon contortus*, with scattered trees. Trees in the wooded grassland included *Daniellia oliveri, Ekebergia senegalensis,* and *M. multinervis*, *T. laxiflora*. *L. lanceolata, P. biglobosa* and the palms like *B. aethiopum*. In each habitat, two permanent transects, each about 210 m long were established. Twenty standard Sherman collapsible live-traps (23 x 9 x 7.5 cm; H.B. Sherman Traps Inc., Florida, USA) were placed at about 10 m intervals along the length of each transect. Traps were baited with a mixture of corn meal and peanut butter, and were set during the day at about 16:30 GMT and checked the following morning from 07:30 to 10:00 GMT. Traps were set for three consecutive nights during the minor rainy season (September 2011), the dry season (January 2012), and the major rainy seasons (June 2012). There was therefore a total trapping effort of 360 trap-nights per habitat and an overall effort of 720 trap-nights.

Small mammal trapping and handling protocols followed standard methods (Wilson et al*.,* 1996; Martin et al., 2001) and complied with the animal care and use guidelines of the American Society of Mammalogists (Gannon et al., 2007). Captured individuals were identified on the spot (when possible), weighed to the nearest gram, sexed using the anal-genital distance (which is shorter in females) (Attuquayefio and Ryan, 2006) and checked for reproductive condition (scrotal testes in males and perforate vagina, enlarged nipples and pregnancy in females). Standard morphometric data, including head and body length (HB), tail length (TL), hind foot length (HF) and ear length (EL) were recorded. Each individual captured was marked by toe-clipping, before being released at the point of capture. Voucher specimens of species that could not be identified on site were sent to the University of Ghana zoological museum for identification.

Analysis of data

Trapping success (Ts)

This was estimated as the number of rodents captured per 100 trap-nights (a trap-night = 1 trap set for 1 night) (Nicolas and Colyn, 2003). Thus,

$$Ts = \frac{Nt \times 100}{Tn} \qquad (1)$$

Relative abundance (Ra)

This was estimated as the number of individuals of the *i*th species caught per 100 individuals. Thus,

$$Ra = \frac{Ni \times 100}{Nt} \qquad (2)$$

Diversity

For diversity of rodents, the Shannon-Wiener index (H') (Pianka, 1966) was estimated as follows:

$$H' = -\Sigma\, pi \ln pi \qquad (3)$$

Where *Nt* is number of rodents captured, *Ni* is the number of individuals of the *i*th species, *Tn* is the total number of trap-nights and *Pi* is the proportion of the *i*th species in the total sample.

Species composition

The similarity of small mammal composition between wooded grassland and forest was computed using Sorenson's index (C_N) (Krebs, 2001) as follows:

$$C_N = 2c/(a+b) \qquad (4)$$

Where *a* and *b* are the number of species at the first and second habitats, respectively, and *c* is the number of species common to the two habitats. The value of C_N may range from 0 to 1, with a value of 0 (zero) indicating that the species composition of the two sites are distinct with no common species shared between them, whereas, a value of 1 means the species composition of both habitats are identical.

RESULTS

Overall trap-success, species richness, relative abundance, composition and diversity

Ninety-six individuals belonging to nine species were recorded over the entire trapping session, giving an overall trap-success of 12.63% and species diversity of 1.16 for the study area (Table 1). Eighty-three individuals (86.5%) of six species were recorded in wooded grassland, while 13 individuals of four species were recorded in the forest. The total trap-success was therefore higher (23.1%) in the wooded grassland than in the forest (3.6%). The total species diversity was however, slightly higher in forest (H' = 1.157) than in wooded grassland (H' = 1.089) (Table 2).

M. erythroleucus recorded the highest captures (68.7%) in wooded grassland, and together with *T. kempi*, comprised 80.7% of the total number of individuals recorded in this habitat. *H. alleni* was the dominant (53.9%) species in forest (Table 2). Species composition was unique for both habitats (Sorenson's index C_N = 0.2), with *M. musculoides* being the only species common to both habitats.

Seasonal changes in species richness, abundance, diversity and composition

Wooded grassland

Species richness was higher in the rainy seasons, with both the major and minor rainy season recording five species each (Table 3). The total number of individuals (abundance), relative abundance and trap-success were highest in the minor rainy season (*Ni* = 34, *Ra* = 35.41%, *Ts* = 28.3%) and lowest in the major rainy season (*Ni* = 22, *Ra* = 22.91%, *Ts* = 18.3%). Species diversity was however, highest (H' = 1.184) in the major rainy season and lowest in the dry season (H' = 0.754) (Table 3). Three species, *M. erythroleucus*, *U. ruddi* and *L. striatus* were recorded in the major and minor rainy season and in the dry season. *M. erythroleucus*, the dominant species in the wooded grassland, was most abundant in the dry season with 24 individuals and least abundant (12 individuals) in the major rainy season. *T. kempi* and

Table 1. Overall total numbers captured (*Ni*), species richness (*Sr*), relative abundance (*Ra*), diversity (*H*') and trap-success (*Ts*) of small mammals recorded in Kogyae Strict Nature reserve (KSNR), Ghana.

Scientific name	Common name	Ni	Ra	Ts (%)
Hylomyscus alleni	Allen's wood mouse	7	7.29%	0.97
Lemniscomys stiatus	Striped grass rat	6	6.25%	0.83
Malacomys edwardsi	Edward's long-footed rat	2	2.08%	0.28
Mastomys erythroleucus	Multimammate rat	57	59.38%	7.92
Mus musculoides	Temminck's pigmy mouse	5	5.21%	0.69
Myomys daltoni	Dalton's mouse	3	3.13%	0.42
Praomys tullbergi	Tullburg's soft-furred mouse	3	3.13%	0.42
Tatera kempi	Kemp's gerbil	10	10.42%	1.39
Uranomys ruddi	Rudd's brush-furred rat	3	3.13%	0.42
Total		96	100%	13.33
Total number of species			9	
Total number of trap-nights			720	
Trapping success			12.63	
Diversity (Shannon-Wiener index *H*')			1.468	

Table 2. Species richness (*Sr*), relative abundance (*Ra*), diversity (*H*') and trap-success (*Ts*) of small mammals recorded in forest and wooded grassland.

Small mammal	Wooded grassland			Forest		
Scientific name	***Ni***	***Ra***	***Ts***	***Ni***	***Ra***	***Ts***
Hylomyscus alleni	0	0	0	7	53.85%	1.94
Lemniscomys stiatus	6	7.23%	1.67%	0	0	0
Malacomys edwardsi	0	0	0	2	15.38%	0.56
Mastomys erythroleucus	57	68.67%	15.83%	0	0	0
Mus musculoides	4	4.82%	1.11%	1	7.69%	0.28%
Myomys daltoni	3	3.61%	0.83%	0	0	0
Praomys tullbergi	0	0	0	3	23.08%	0.83%
Tatera kempi	10	12.05%	2.78%	0	0	0
Uranomys ruddi	3	3.61%	0.83%	0	0	0
Number of individuals	83	100%	23.06%	13	100%	3.61%
Number of species	6	-	-	4	-	-
Number of trap-nights	360	-	-	360	-	-
Relative abundance	86.46%	-	-	13.54%	-	-
Trapping success	23.01%	-	-	3.61%	-	-
Diversity index (*H*')	1.089	-	-	1.157	-	-

M. daltoni were recorded in at least two seasons, while *M. musculoides* was recorded in the minor rainy season only, *T. kempi* recorded the highest trapping success (5%) and relative abundance (60%) during the major rainy season (Table 3).

Forest

In the forest habitat, species richness and diversity were highest (3 species, H' = 1.099) in the major rainy season and lowest (1 species, H' = 0) in the dry season. Relative abundance and trap-success were highest (Ra = 5.0%, Ts = 46.1%) in the major rainy season and lowest (Ts = 1.7%, Ra = 23.4%) in the minor rainy season (Table 3). *Praomys tullbergi* was recorded during the major and minor rainy seasons only, while *H. alleni* was recorded during the major rainy and dry seasons, but not in the minor rainy season. *H. alleni* was also the only species recorded during the dry season. *Malacomys edwardsi* was recorded in the major rainy season only, whereas *M. musculoides* was recorded in the minor rainy season only (Table 4). *P. tullbergi, M. edwardsi* and *H. alleni* were equally abundant (33.33% each) during the major rainy season. *M. musculoides* and *P. tullbergi* also recorded similar relative abundance (50% each) and trap success

Table 3. Seasonal changes in overall species richness, abundance, diversity and trap-success in the different habitats in the study area.

Parameter	Habitat					
	Wooded grassland			Forest		
	R_1S	R_2S	DS	R_1S	R_2S	DS
Number of trap-nights	120	120	120	120	120	120
Number of species	5	5	4	3	2	1
Number of individuals	22	34	27	6	2	5
Relative abundance	22.91%	35.41%	28.13%	6.25%	2.10%	5.21%
Trap-success	18.30%	28.30%	22.50%	5.00%	1.70%	4.20%
Diversity index (*H*')	1.184	0.955	0.754	1.099	0.693	0

R_1S = Major rainy season; R_2S = minor rainy season; DS = dry season.

Table 4. Seasonal changes in species composition, relative abundance and trap-success of small mammals in the wooded grassland.

Small mammals	Major rainy season		Minor rainy season		Dry season	
	Ni	*Ts* (%)	*Ni*	*Ts*(%)	*Ni*	*Ts* (%)
			Wooded grassland			
Mastomys erythroleucus	12	10	21	17.50	24	20.00
Mus musculoides	0	0	4	3.33	0	0
Tatera kempi	6	5	4	3.33	0	0
Uranomys ruddi	1	0.83	1	0.83	1	0.83
Myomys daltoni	1	0.83	0	0	2	1.67
Lemniscomys stiatus	2	1.67	1	0.83	3	2.50
			Forest			
Praomys tullbergi	2	1.67	1	0.83	0	0
Malacomys edwardsi	2	1.67	0	0	0	0
Hylomyscus alleni	2	1.67	0	0	5	4.16
Mus musculoides	0	0	1	0.83	0	0

(0.83% each) during the minor rainy season (Table 4).

Seasonal changes in sex-ratio

For individual species, sample sizes were too small to indicate any seasonal trends in sex ratio. Sex-ratio of *M. erythroleucus*, the most abundant species in the study area, was female-biased (♂1:♀2) in the major rainy season, male-biased (♂1.6:♀1) in the dry season and unity (♂1:♀1) in the minor rainy season.

Seasonal changes in breeding activity

Small mammals showed signs of breeding activity during the major and minor rainy season, with 93.3% of males having scrotal testes and 77% of females with perforate vaginas during the rainy seasons. All the captured males of *M. erythroleucus* had scrotal testes in the major and minor rainy seasons, but only 46% had scrotal testes in the dry season. The highest percentage (75%) of *M. erythroleucus* females with perforate vaginas was recorded in the dry season, and the lowest (18.2%) in the minor rainy season. All the individuals recorded in forest showed signs of breeding activity during the wet season.

DISCUSSION

Relative abundance, diversity and composition

The small mammal species richness at the KSNR (9 species) compared well with that obtained in the Accra Plains of Ghana (Decher and Bahien, 1999) and the Muni-Pomadzi Ramsar site in the Central region of Ghana (Attuquayefio and Ryan, 2006). However, it fell short of the 11 species reported from the Amansie West District of the Ashanti Region (Ofori et al., 2013) and the 14 species in the Western Region (Yeboah, 1998). The low abundance and diversity of small mammals recorded in this study could be, in part, due to the low trapping effort. It normally takes considerable trapping effort to capture naturally rare species that have low population sizes and small distributional ranges (Fichet-Calvet et al., 2009a). Placing the traps on the ground only, might also have resulted in a bias of trapping effort towards forest-floor dwelling species.

Species composition at the study area was typical of West African small mammal assemblage (Yeboah, 1998; Decher and Bahian, 1999; Attuquayefio and Ryan, 2006; Fichet-Calvet et al., 2009a; Nicolas et al*.,* 2010). The distinctiveness of species composition in the two habitats corresponded well with the habitat type. *P. tullbergi*, *H. alleni* and *M. edwardsi*, which are known forest-associated species, were recorded in forest only, whereas *M. erythroleucus, L. striatus, T. kempi* and *U. ruddi* are typical open grassland species with some preference for farmbush and forest clearings (Happold, 1987; Decher and Abedi-Lartey, 2002; Ofori et al*.,* 2013a). *Mus musculoides* and *M. daltoni* are widespread habitat generalists that occur in a wide range of habitats and seem to depend on leaf litter (Decher and Abedi-Lartey, 2002). The high trapping success and relative abundance of *M. erythroleucus* in wooded grassland was not unexpected. The species is well-documented as very dominant in open grasslands and thickets, as well as in more arid areas (Decher and Bahian, 1999; Attuquayefio and Ryan, 2006; Makundi et al*.,* 2009). The local and regional abundance of *M. erythroleucus* could be explained by its opportunistic feeding on grasses, leaves, seeds, seedlings, and insects, and its ability to adapt to modified habitats from open woodland to perennial grassy habitats (Decher and Bahian, 1999).

West African forests are usually dominated by either *P. tullbergi* or *Hylomyscus* sp. (Decher and Bahian, 1999). Most small mammal studies in forests in Ghana have reported *P. tullbergi* as the dominant species (Cole, 1975; Jeffrey, 1977; Garshong et al., 2013; Ofori et al., 2013b). In this study however, *H. alleni* was the most abundant forest-specialist species, even though the numerical difference in individual numbers between these species was not as large as their relative abundance scores might suggest.

Seasonal changes in species richness, abundance, diversity and composition

Seasonal variations in rodent communities were evident in the study area, supporting previous studies (Fichet-Calvet et al., 2009b; Makundi et al., 2009; Ofori et al., 2013a). The high species richness and abundance in the rainy season could be attributed to abundance of food and vegetation cover for small mammals during the wet season (Habtamu and Bekele, 2012). The high trap-success and relative abundance in the dry season could be attributed to the mono-dominance of *M. erythrleucus*, an opportunistic feeder, in the dry season (Decher and Bahian, 1999).

Seasonal changes in sex-ratio and breeding activity

Even though the male : female ratio of small mammals in this study did not deviate very much from unity, males were generally more abundant than females. This observation is supported by several other studies (Nicolas and Colyn, 2003; Garshong and Attuquayefio, 2013; Ofori et al*.,* 2013ab). This may be because dispersal in small mammals is male-biased, increasing the chance of males encountering traps and getting captured (Garshong and Attuquayefio, 2013; Ofori et al*.,* 2013b).

Overall breeding pattern of rodents in the study area was seasonal and related to rainfall. It is probably because the abundance of protein-rich diets like foliage, seedlings and insects, and lush vegetation cover during the wet season provide adequate security for lactating females and their offspring (Attuquayefio and Wuver, 2003; Nicolas and Colyn, 2003; Makundi et al*.,* 2005, 2009; Fichet-Calvet et al., 2009b; Habtamu and Bekele, 2012). The findings of this study also showed that breeding activity in *M. erythroleucus* continued during the dry season indicating perhaps, a year-round breeding activity in this species (Fichet-Calvet et al*.*, 2009b). Further studies will however be needed to confirm this, even though opportunistic feeding behaviour of the species coupled with a year-long breeding activity could account for its local dominance.

The present study is the first detailed survey of small mammals at the Kogyae Strict Nature Reserve, and the forest-savanna transition of Ghana. The findings of this study therefore will serve as baseline information for future monitoring programmes, which are necessary to evaluate impacts of environmental changes on small mammals.

Conflict of interests

The authors did not declare any conflict of interest.

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Woody species diversity of *Vitellaria paradoxa* C.F. Gaertn traditional agroforests under different land management regimes in Atacora district (Benin, West Africa)

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Agricultural production in northern Benin is characterized by smallholder traditional agroforestry systems, with on-farm remnant tree species. Among its numerous advantages, agroforestry is known for its valuable contribution to biodiversity conservation. This study quantifies the importance of *Vitellaria paradoxa* C.F. Gaertn agroforests in terms of woody species conservation in Atacora district in Benin. Forest inventories were performed within 50×50 m plots constructed on a net grid map of Atacora district. Diversity indices were computed for both adult and juvenile species in two land management regimes: fields and fallows. Overall 41 woody species were recorded; 28 in fields and 36 in fallows. Taking into account matured and juvenile individuals, the diversity of woody species increased: 86 species in total; 69 species in fields and 78 in fallows. The biodiversity of *V. paradoxa*'s agroforestry parklands increases from fields to fallows, and decreases from bulk species (considering mature and juvenile species) to adult ones. *Leguminosae* and *Combretaceae* were the most abundant families registered. From the Cover Value Index, *V. paradoxa*, *Parkia biglobosa*, *Lannea microcarpa*, *Lannea acida* and *Diospiros mespiliformis* were the most abundant species. Support for maintaining this kind of agricultural system is needed, as this exemplifies the synergy for providing, provisioning and supporting services and biodiversity conservation.

Key words: Agroforestry, conservation, ecosystem services, farmland, shea tree.

INTRODUCTION

Agroforestry, the integration of trees with annual crop cultivation, livestock production and other farm activities, is a series of land management approaches practiced by more than 1.2 billion people worldwide (Jamnadass et al.,

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2013). According to some projections, the area of the world under agroforestry will increase substantially in the near future (Albrecht and Kandji, 2003). Therefore, agro-forestry that characterize agricultural areas, appears to be the future landscape in West Africa sub-region, where agricultural land covers more than double of the area covered by forests. The ratio between agricultural land and forests is expected to rise due to population growth inappropriate agricultural production mainly. In order to feed the burgeoning global population, agricultural production has to grow in the coming decades. This makes trees on agricultural land a promising tool to address climate change mitigation and adaptation (Verchot et al., 2007; Henry et al., 2012) while enhancing biodiversity and human populations' livelihood.

The importance of agriculture in sub-Sahara African countries calls for new insights and consideration of agricultural activities not as a source of biodiversity loss but rather as a mean of its conservation considering the area covered by agroforestry. These strategies support the development of plans for ecoagriculture, a new type of agriculture that combines objectives of enhancing rural livelihoods, ensuring food security, and conserving biodiversity in the same landscape. ecoagriculture is advocated by many researchers to complement other conservation methods (McNeely and Scherr, 2003; McNeely and Schroth, 2006; Scherr and McNeely, 2002, 2012).

The integration of trees and crops is an environmentally sound land management conducive to moisture, soil conservation, and thus to high productivity (Traoré, 2003; Tomlinson et al., 1995; Jonsson et al., 1999). Trees in agroforestry systems provide traditional medicines as well as basic food commodities, including a variety of gums, oils, proteins, fruits, and drinks to a large number of people (Atakpama et al., 2012; Avocèvou-Ayisso et al., 2012; Edwige et al., 2012). There is ample evidence of indigenous knowledge and practices involved in enhancing biodiversity at the landscape level (Gadgil et al., 1993). Some food-providing trees and palms, especially fruit-producing ones, have been managed by people in a transition from the wild to cultivation in farmland for millennia, resulting in complex agroforestry systems that contain many different foods (Torquebiau, 1985)

Shea tree, *Vitellaria paradoxa* C.F. Gaertn, a tree belonging to Sapotaceae's family, is the most common species found in most of the traditional agroforestry parklands in West Africa (Breman and Kessler, 2011; Boffa, 2000; Aleza et al., 2015). In Atacora district in Benin, shea agroforests provide to rural households 36 to 46% of their income through the money gained from selling shea-based products (Gnanglé et al., 2009; Dah-Dovonon and Gnangle, 2006).

Previous studies in the region addressed the shea agroforests' population structure, land management and productivity (Djossa et al., 2008; Adissatou and Brice, 2009). Some showed its socio-economic and use values (Agbahungba et al., 2001; Assogbadjo et al., 2012) and its population adaptation along different ecological zones in Benin (Glèlè et al., 2011). Considering its wide distribution, agroforestry has the potential to enhance biodiversity conservation through *in situ* conservation. But the contribution of shea agroforests to the conservation of biodiversity at landscape level lacks scientific evidences.

For this reason, this study (i) examines the diversity of woody species in two land management regimes of Shea agroforests in Atacora district and (ii) compares the state of biodiversity conservation between adult woody species and the overall species taking into account juveniles and adults individuals. Addressing these objectives will show human impact on the agroforestry systems' physiognomy and biodiversity conservation. It is expected that this study will help to improve adoption of agroforestry projects and provide insights for farmers' management practices.

MATERIALS AND METHODS

Study area

Benin is divided into 12 districts which are further subdivided into 77 communes. Atacora district, concerned by the current work, is the northwestern one and covers a surface area of 20 459 km^2 over 112 622 km² of the country's area. Four over nine of Atacora communes have been investigated in the current study. These four communes cover 12,117 km^2 and are the following: Tanguieta, Materi, Cobly and Boukombé (Figure 1), all located in the Sudanian zone. Atacora district is one of the research sites of the WASCAL program (West African Science Service Center on Climate Change and Adapted Land Use) under which this study is enrolled. According to 2013 census, the district has a population of 769,337 inhabitants over 9,983,884 million of the total population (RPG4, 2013). A range of mountains extends along the northwest border and into the northeast Togo. Three major soil types can be found: tropical ferruginous soils, hydromorphic soils, and rough and undeveloped mineral soils. The climate in Atacora is characterized by two seasons: one rainy season from May to September, and one dry season for the rest of the year (Aregheore, 2009). The annual amount of rainfall varies between 900 and 1100 mm (Benin Republic, 1996). Variations in temperature increase when moving north through savannah towards the Sahel. A dry wind from the Sahara called Harmattan blows from December to March. On the social aspect, 70% of the population is rural with agricultural production the main activity. A wide variety of annual crops are grown: cotton, maize, sorghum, groundnut, cowpea, millet etc., associated with scattered multipurpose trees such as *V. paradoxa* and *Parkia biglobosa* Jacq. Dong (Aregheore, 2009; Vissoh et al., 2004).

Sampling design and data collection

Two land management regimes were examined in this study, namely fields and fallows. Fields are areas where annual crops are cultivated, whereas fallows are areas previously cultivated and left for a medium or long period to re-establish its vegetation structure and soil fertility. These are the most important land management regimes in Shea agroforests defined by scholars (Lovett and Haq, 2000; Boffa, 2000; Okiror et al., 2012; Akais Okia et al., 2005).

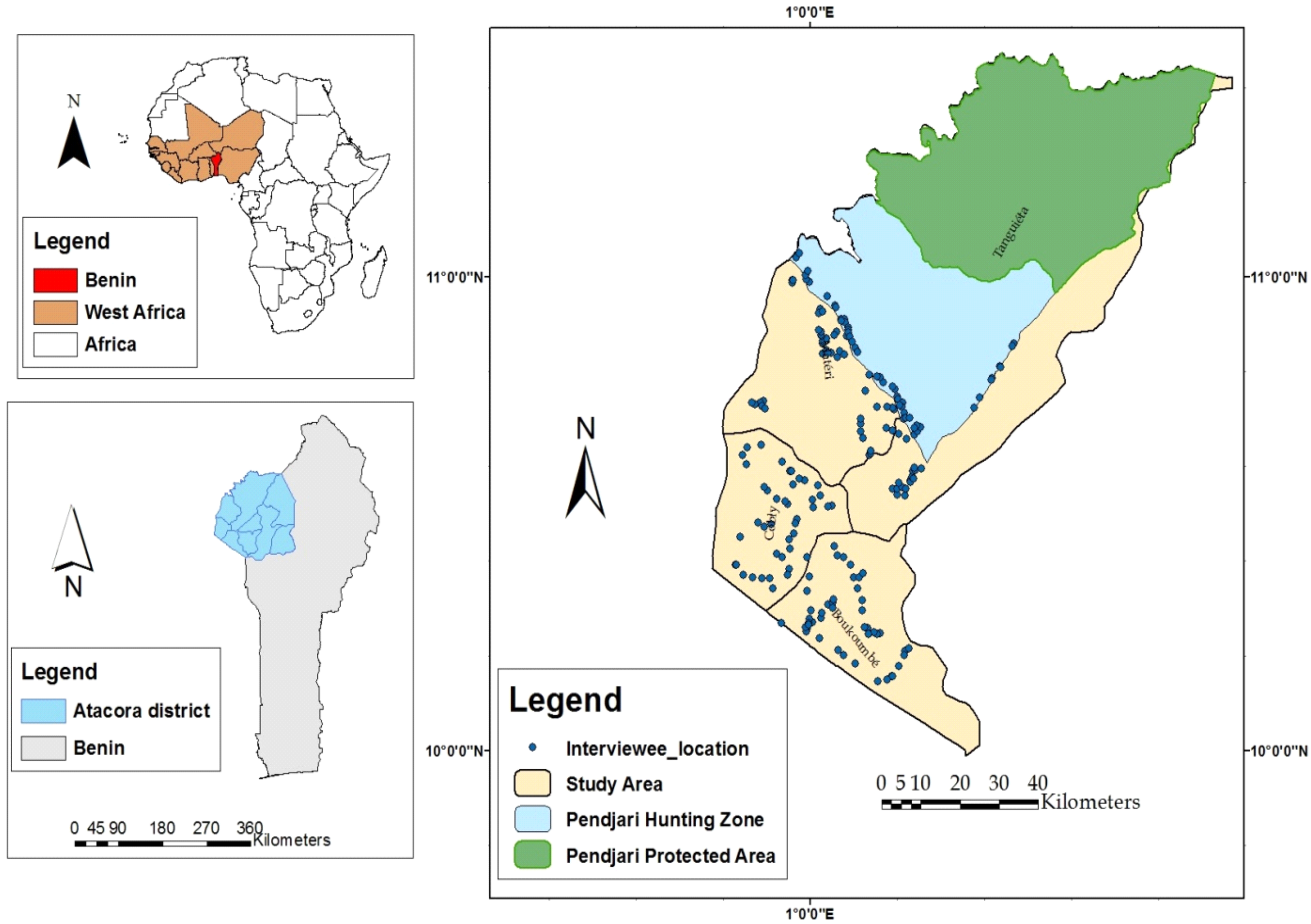

Figure 1. Sample sites within Atacora district in Benin.

The sampling method used is a cluster sampling. First, squares sized 10 x 10 km were chosen on a net grid map of Atacora's district. Within each selected square, one to ten plots sized 50 x 50 m (2500 m^2) were established according to the availability of shea stands and the accessibility of the considered area. Plots size was justified by the fact that they were successfully used in the same region during previous parklands studies (Wala et al., 2005; Byakagaba et al., 2011; Padakale et al., 2015). Overall, data were collected from 213 plots: 50 in Boukombé, 39 in Cobly, 47 in Materi and 76 in Tanguieta (Figure 1). The first plot was located randomly whilst the following ones were established at least at 100 m away from the first one. In each plot, all woody species were recorded and dendrometric parameters (circumference and total height) measured for adult trees species with diameter at breast height (DBH) ≥10 cm while those with DBH <10 cm were considered as juveniles. Species names were further conformed to those set by Brunel et al. (1984) and Akoègninou et al. (2006). Moreover, geographical coordinates of each plot were registered for cartography purposes.

Data analysis

Data collected were processed using Minitab 16, and ArcGIS 10. The first software was used for diversity indices calculation, the second one for statistical analysis where Fisher test was used to verify hypothesis in the difference of variables. The third one was used for mapping.

Alpha diversity indices of all species

All species encountered in this study were categorised into their respective families and genera according to those set by (Brunel et al., 1984; Akoègninou et al., 2006). Alpha diversity indices were computed for bulk species (both adult and juveniles). Each land management regime was characterized by alpha diversity indices: species richness (*S*), Shannon-Wiener diversity index (*H*) and Pielou evenness index (E) (Brower and Zar, 1984). The Pielou's evenness measures the similarity of the abundance of the different woody species sampled. Its value varies between 0 and 1. The value tends to 0 when one or few species had high abundance than others and 1 in the situation where all species had equal abundance (Magurran, 2004).

The species richness *S* is the total number of species recorded in a given land management regime. Shannon diversity index (*H*) was expressed as:

$$H = -\sum_{i=1}^{S} \left(\frac{Ni}{N}\right) \log\left(\frac{Ni}{N}\right) \quad (1)$$

Where *Ni* is the number of species *i*, *N* the total number of individuals sampled in a considered land management regime and *S* the total number of species encountered.

Whereas, Pielou evenness index (E) is computed as follows:

$$E = -\frac{\sum_{i=1}^{S}\left(\frac{Ni}{N}\right)\times\log_2\left(\frac{Ni}{N}\right)}{\log_2(S)} \quad (2)$$

Diversity indices of adult woody species

In addition to alpha diversity indices, woody species diversity indices were computed for adult woody species and also for the two distinguished land management regimes. Target indices are the cover value index (CVI), which was defined by Förster (Bailey and Dell, 1973) and used by de Olivera-Filho et al. (1989), the importance value index (IVI), (Curtis and McIntosh, 1950; Cottam and Curtis, 1956; Pereki et al., 2013) and the Sorenson-Dice coefficient (β) to compare the similarity of fields and fallows biodiversity.

CVI is used to evaluate the importance of the species within each of the land management regime. It gives equal weights to the species density through the number of individuals and equal size through the total basal area of the individual. CVI is expressed as:

CVI = RDe + RDo (3)

where, RDe, the relative density is computed as follows:

RDe = (number of individuals of species *i* / total number of individuals) × 100

RDo, the relative basal area is obtained by using the following formula:

RDo = (total basal area for species *i* / total basal area of all species) × 100

$$RDo = \frac{g_i}{\sum_{i=1}^{n} g_i} \quad (4)$$

g, the basal area is computed as follows:

$$g_i = \frac{\pi}{4} d_i^2 \quad (5)$$

Where, d_i is the DBH of species *i*

The importance value index (IVI) is calculated as a sum of relative frequency, relative density and relative basal area of each species. The following formula was used:

IVI = CVI + RF (6)

where RF, the relative frequency is calculated as follows:

RF = (frequency of species i / sum frequencies of all species) × 100 (6)

Sorenson-dice coefficient is expressed as follows:

$$\beta = \frac{2C}{A+B} \quad (7)$$

where, C is the number of species common to the two land management regimes, A is the number of species recorded in fields and B is the number of species registered in fallows.

RESULTS

Alpha diversity of woody species in fields and fallows

Overall, 1622 adult trees were measured over a total of 53.25 ha of land. Within this area, 86 woody species were recorded: 69 in fields and 78 in fallows (Table 1). The two land management regimes have many species in common. This is shown by Sorenson-Dice coefficient values: 0.72 for adult species and 0.79 for both juveniles and adult. Fisher test showed a significant difference in species richness between fields and fallows (p = 0.000). An average of 8±4 and 11±6 species per plot was counted for fields and fallows, respectively.

The 69 woody species in fields belonged to 57 genera and 30 families. Among the dominant species recorded are *V. paradoxa* (found 115 times within 115 plots), *Combretum collinum* Fresen*.* (55), *Parkia biglobosa* (53), *Stereospermum kunthianum* Cham*.* (47) and *Annona senegalensis* Pers*.* ssp*. oulotrieha* Le Thomas (45). The most represented families are Leguminosae (12 species), Combretaceae and Rubiaceae (7 species), Moraceae (6 species) and Anacardiaceae (4 species). The alpha diversity estimated by Shannon is 1.56 and Pielou evenness index is 0.85 (Table 1).

In fallow areas, a total of 78 species belonging to 65 genera, and 32 families were recorded. Among the dominant species recorded are *V. paradoxa* (found 97 time within 97 plots), *C. collinum* Fresen*.* (59), *S. kunthianum* Cham*.* (49), *A. senegalensis* Pers*.* ssp. *oulotrieha* Le Thomas (48), and *Acacia polyacantha* Willd*.* ssp. *campylacantha (*Hochst.ex A.Rich*.)* (44). The most well represented families were Leguminosae (15 species), Combretaceae (8 species), Anacardiaceae (7 species), Rubiaceae (6 species) and Meliaceae (4 species). The Shannon diversity index is estimated to 1.63 and Pielou eveness index to 0.86 (Table 1).

Though fallows appear to be more diversified, Fischer test showed that land management regime does not influence species richness (p = 0.112). However, Fisher test showed significant differences between adult species diversity and bulk ones in fields (p = 0.00) and fallows (p = 0.00) (Appendix 1b).

Diversity of adult woody species

Overall, *V. paradoxa* agroforests registered 41 woody species. Among 69 species found in fields, 28 were adults belonging to 24 genera, and 14 families. Table 2 shows adults woody species vegetation indices. According to the importance value index (Table 2), the

Table 1. Alpha diversity of woody species within *V. paradoxa* agroforestry parklands of Atacora in Benin. Values in parentheses are overall species' indices.

Parameter	Fields	Fallows
Species richness	28 (69)	36 (78)
Shannon diversity index	0.46 (1.56)	0.59(1.63)
Pielou evenness index	0.32 (0.85)	0.38 (0.86)

Table 2. Vegetation indices of adult woody species within *V. paradoxa* parklands in Atacora (Benin, West Africa); bold fonts denote the five most important agroforestry species.

Family	Fields Species name	Ni	Rde	Rdo	CVI	Rn	RF	IVI
Anacardiaceae	***Lannea acida* A.Rich. s.l.**	**21**	**2.57**	**1.58**	**4.15**	**10**	**4.22**	**8.37**
Anacardiaceae	***Lannea microcarpa* Engl. & Krause**	**8**	**0.98**	**1.46**	**2.44**	**7**	**2.95**	**5.39**
Anacardiaceae	*Mangifera indica* L.	4	0.49	1.58	2.07	4	1.69	3.76
Anacardiaceae	*Anacardium occidentale* L.	1	0.12	0.02	0.14	1	0.42	0.56
Arecaceae	*Borassus aethiopum* Mart.	1	0.12	0.27	0.40	1	0.42	0.82
Bombacaceae	*Adansonia digitata* L.	2	0.24	4.04	4.28	2	0.84	5.12
Bombacaceae	*Bombax costatum* Pellegr. & Vuillet	2	0.24	0.95	1.19	2	0.84	2.04
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	5	0.61	0.29	0.90	2	0.84	1.75
Combretaceae	*Anogeissus leiocarpa* (De.) Guill. & Perr.	6	0.73	0.27	1.00	5	2.11	3.11
Combretaceae	*Combretum collinum* Fresen.	3	0.37	0.10	0.46	1	0.42	0.89
Combretaceae	*Terminalia laxijlora* Engl.	1	0.12	0.13	0.26	1	0.42	0.68
Combretaceae	*Terminalia macroptera* Guill. & Perr.	1	0.12	0.02	0.14	1	0.42	0.56
Ebenaceae	***Diospyros mespiliformis* Hochst. Ex A. De.**	**13**	**1.59**	**1.49**	**3.09**	**9**	**3.80**	**6.88**
Leguminosae	***Parkia biglobosa* (Jacq.) R.Br. ex Benth.**	**90**	**11.02**	**20.41**	**31.43**	**48**	**20.25**	**51.68**
Leguminosae	*Prosopis africana* (Guill. & Perr.) Taub.	3	0.37	0.32	0.68	3	1.27	1.95
Leguminosae	*Pterocarpus erinaceus* Poir.	3	0.37	0.34	0.71	3	1.27	1.97
Leguminosae	*Tamarindus indica* L.	1	0.12	0.11	0.23	1	0.42	0.65
Meliaceae	*Azadirachta indica* A.Juss.	11	1.35	0.46	1.81	5	2.11	3.92
Meliaceae	*Ficus sycomorus* L.	4	0.49	0.52	1.01	3	1.27	2.28
Meliaceae	*Khaya senegalensis* (Desr.) A.Juss.	3	0.37	2.97	3.34	3	1.27	4.61
Meliaceae	*Ficus exasperata* Vahl	2	0.24	1.68	1.92	2	0.84	2.77
Meliaceae	*Ficus platyphylla* Delile	1	0.12	0.14	0.27	1	0.42	0.69
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay	1	0.12	0.16	0.28	1	0.42	0.71
Rubiaceae	*Mitragyna inermis* (Willd.) Kuntze	1	0.12	0.03	0.15	1	0.42	0.57
Sapotaceae	***Vitellaria paradoxa* C.F.Gaertn. ssp. *Paradoxa***	**623**	**76.25**	**59.90**	**136.15**	**115**	**48.52**	**184.68**
Sterculiaceae	*Sterculia setigera* Delile	1	0.12	0.07	0.19	1	0.42	0.61
Tiliaceae	*Grewia carpinifolia* Juss.	1	0.12	0.02	0.15	1	0.42	0.57

Table 2. Vegetation indices of adult woody species within *V. paradoxa* parklands in Atacora (Benin, West Africa); bold fonts denote the five most important agroforestry species.

Verbenaceae	*Vitex doniana* Sweet	4	0.49	0.68	1.17	3	1.27	2.43
Anacardiaceae	*Anacardium occidentale* L.	3	0.37	0.14	0.51	1	0.45	0.96
Anacardiaceae	*Haematostaphis barteri* Hook.F.	3	0.12	0.02	0.15	2	0.45	0.6
Anacardiaceae	*Lannea barteri* (Olïv.) Engl.	1	0.12	0.86	0.99	1	0.45	1.44
Anacardiaceae	***Lannea acida* A.Rich. s.i.**	**32**	**3.98**	**3.9**	**7.87**	**15**	**6.73**	**14.6**
Anacardiaceae	***Lannea microcarpa* Engl. & Krause**	**20**	**2.48**	**1.24**	**3.73**	**7**	**3.14**	**6.86**
Anacardiaceae	*Mangifera indica* L.	1	0.12	0.15	0.27	1	0.45	0.72
Anacardiaceae	*Sclerocarya birrea* (A.Rich.) Hochst.	2	0.37	0.45	0.82	2	1.35	2.17
Araliaceae	*Cussonia arborea* Hoehst. ex A. Rich.	1	0.12	0.24	0.36	1	0.45	0.81
Bignoniaceae	*Stereospermum kunthianum* Cham.	9	0.75	1.41	2.16	4	2.69	4.85
Bombacaceae	*Bombax costatum* Pellegr. & Vuillet	7	0.87	0.93	1.8	3	1.35	3.14
Combretaceae	*Anogeissus leiocarpa* (De.) Guill. & Perr.	9	1.12	0.5	1.62	6	2.69	4.31
Combretaceae	*Combretum collinum* Fresen.	6	0.75	0.19	0.94	3	1.35	2.28
Combretaceae	*Pteleopsis suberosa* Engl. & Diels	1	0.25	0.49	0.74	1	0.9	1.63
Combretaceae	*Terminalia laxiflora* Engl.	4	0.12	0.74	0.86	3	0.45	1.31
Combretaceae	*Terminalia macroptera* Guill. & Perr.	2	0.25	0.05	0.3	2	0.45	0.75
Ebenaceae	*Diospyros mespiliformis* Hochst. Ex A. De.	4	0.5	0.22	0.72	2	0.9	1.62
Euphorbiaceae	*Brideliaferruginea* Benth.	1	0.12	0.02	0.14	1	0.45	0.59
Leguminosae	*Acacia gourmaensis* A.Chev.	2	0.25	0.05	0.3	2	0.9	1.2
Leguminosae	*Acacia polyacantha* Willd. ssp. *campylacantha* (Hochst. ex A.Rich.)	1	0.12	0.03	0.15	1	0.45	0.6
Leguminosae	***Daniellia oliveri* (Rolfe) Hutch. & Dalziel**	**14**	**1.74**	**0.92**	**2.65**	**6**	**2.69**	**5.35**
Leguminosae	*Entada africana* Guill. & Perr.	4	0.5	0.15	0.65	2	0.9	1.54
Leguminosae	***Parkia biglobosa* (Jacq.) R.Br. ex Benth.**	**66**	**8.2**	**13.04**	**21.24**	**32**	**14.35**	**35.59**
Leguminosae	*Prosopis africana* (Guill. & Perr.) Taub.	2	0.12	0.21	0.34	2	0.45	0.79
Leguminosae	*Pterocarpus erinaceus* Poir.	3	0.12	0.09	0.21	3	0.45	0.66
Leguminosae	*Tamarindus indica* L.	2	1.12	1.21	2.33	1	1.79	4.13
Meliaceae	*Azadirachta indica* A.Juss.	4	0.5	0.25	0.74	2	0.9	1.64
Meliaceae	*Khaya senegalensis* (Desr.) A.Juss.	1	0.37	0.47	0.84	1	0.45	1.29
Moraceae	*Ficus exasperata* Vahl	2	0.5	0.28	0.78	2	1.35	2.12
Moraceae	*Ficus sycomorus* L.	3	0.25	0.23	0.48	1	0.9	1.38
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay	1	0.12	0.32	0.45	1	0.45	0.9
Polygalaceae	*Securidaca longepedunculata* Fresen.	1	0.25	0.19	0.43	1	0.9	1.33
Sapotaceae	***Vitellaria paradoxa* C.F.Gaertn. *ssp. Paradoxa***	**579**	**71.93**	**69.41**	**141.34**	**97**	**43.5**	**184.83**
Sterculiaceae	*Sterculia setigera* Delile	6	0.12	0.03	0.15	6	0.45	0.6
Tiliaceae	*Grewia carpinifolia* Juss.	1	0.37	0.11	0.49	1	0.45	0.93
Verbenaceae	*Vitex doniana* Sweet	5	0.62	0.98	1.6	5	2.24	3.84
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	3	0.37	0.49	0.87	2	0.9	1.76

Ni = Overall number of individuals of specie i, RDe = relative density, RDo = relative basal area, Rn = richness number, RF = relative frequency, CVI = cover value index, IVI = importance value index.

five most abundant species are *V. paradoxa* (184.27%), *P. biglobosa* (51.51%), *L. acida* (8.33 %), *Diospiros mespiliformis* Hochst. Ex A. De. (6.86%) and *L. microcarpa* (5.37%). In terms of families' representation, Meliaceae, Anacardiaceae, Combretaceae and Leguminosae are the most represented families. In fields, the Shannon diversity index is 0.46 and the Pielou eveness index is 0.32. The complete list of woody species registered in Atacora and their frequency is found in appendix 1a.

On the other hand, fallow areas registered a total of 36 adult species representing about 22% more species than that of fields. These species belonged to 31 genera and 17 families. The IVI showed that, the five most abundant species found in fallows were: *V. paradoxa* (184.75%), *P. biglobosa* (35.58%), *L. acida* (14.6%), *L. microcarpa* (6.86%) and *D. oliveri* (5.35%) (Table 2). The most represented families in fallows are Leguminosae (8 species), Anacardiaceae (7 species) and Combretaceae (5 species). The Shannon diversity index is 0.59 and Pielou evenness index is 0.39.

DISCUSSION

Adult woody species richness was estimated to be 41 tree species in Atacora. Comparable to our findings is report by Augusseau et al. (2006) and Ouinsavi and Sokpon (2008) who recorded respectively, 50 tree species in agroforestry parklands of the sub-humid part of Burkina Faso, and 45 species in *Milicia excelsa* (Welw.) C.C.Berg agroforesty parklands in Benin. On the other hand, our findings are higher than Fifanou et al. (2011) findings with 21 species in Pendjari Biosphere Reserve in Benin. Wala et al. (2005) recorded 25 species in Doufelgou's parklands in northern Togo and Folega et al. (2011) found 29 species under fallow in protected areas of Northern Togo. Cline-Cole et al. (1988) also found less species (22) in Kano's farmed parklands in northern Nigeria with almost the same agroecological zone. The differences in species richness could be explained by factors such as sampling design, sampling effort or both. In eastern and central Africa, Kindt et al. (2005) found 127 tree species in western Kenya's farms. The difference in woody species diversity between our study and that of Kindt et al. (2005) could be due to the study area's ecoregion, which in Kenyan case belongs to the Victoria Basin forest-savanna mosaic ecoregion (Kindt et al., 2005). Indeed, the later is known for its high species diversity and endemism which results from the mixture of habitat types. Wala et al. (2009) reported that woody species diversity in parkland varied according to the latitudinal gradient in Togo. Moreover, conservation of woody species in agricultural areas is directed by the use and knowledge of local communities and the traditional management practices (Ræbild et al., 2011).

Shannon diversity index and Pielou eveness index recorded in fields are similar to that of fallows. This can be explained by the interconnectivity existing between the two land management regimes. Species that are conserved in fields are selected among those that grow in natural areas. The selected species are conserved and managed until the depletion of soil fertility and shifting from field to fallow.

Leguminosae and Combretaceae were the most important families registered in Atacora district. Previous studies found similar results in northern Togo's agroforestry systems (Wala et al., 2005, 2009; Folega et al., 2011; Kebezikato et al., 2015). The current study site and the above ones are located in Sudanian tropical climate, which vegetation is dominated by families mentioned earlier. Indeed, Combretaceae and Leguminosae are part of the most dominant families in the Sudanian tropical zones (Aubreville, 1950). In addition, Leguminosae trees are known for their importance in agroforestry and silvo-pastoral systems, which function primarily in restoring and maintaining soil fertility through their ability to establish in nitrogen-deficient soils and the benefits of the nitrogen fixed to associated crops (Dommergues, 1987; Danso et al., 1992; Sprent, 1999).

Abundance of *V. paradoxa*, *P. biglobosa*, *L. microcarpa, L. acida* and *D. mespiliformis* is the result of farmers willingness to conserve trees in agricultural areas. Many researchers mentioned the above species as the most dominant one in agroforestry systems of the Sudanian zone (Wala et al., 2005; Folega et al., 2011; Aleza et al., 2015). Species listed in annex 1 are conserved in fields and fallows by local farming communities. Their presence and abundance confirm their importance for local communities (Agbahungba et al., 2001; Dah-Dovonon and Gnanglé, 2006; Gnanglé et al., 2009; Assogbadjo et al., 2012).

The woody species diversity associated with shea agroforestry parklands increases from fields to fallows, and decreases from bulk species to adult ones. This aspect reflects the selective character of conservation when it comes to species associate with crops. Many tree species grow naturally in lands allocated to agriculture, but not all of them reach the adult stage within the study area. Only those that are important for farmers and pastoralists are conserved and managed until their adult stage. Undesirable and unwanted species are removed during agricultural activities such as tillage, weeding, pruning, etc.

On-farm trees are integrally part of agricultural systems in Atacora as well as in other places in West Africa for their multiple uses. Nowadays, in addition to the uses and importance of trees in farmlands, they play a major role in the context of climate change. Indeed, some researchers have proposed agroforestry as a potential strategy for helping subsistence farmers reduce their vulnerability to climate change (Challinor et al., 2007; Verchot et al. 2007). Agroforestry among the land uses analyzed in the land-use, land-use change and forestry report of the IPCC (Intergovernmental Panel on Climate Change) offered the highest potential for carbon sequestration in non-Annex I countries (they are countries that have ratified or acceded to the UNFCCC but are not included in Annex I which means they are not required to reduce their greenhouse gas emissions)

Agricultural land use affects large parts of terrestrial area, so its contribution to biodiversity is critical for successful conservation projects. Lands used for agricultural activities are estimated to 28.31% of Benin surface area and are expected to rise in the future (FAO, 2010). There is possibility to simultaneously conserve biodiversity while reducing farmers' vulnerability to climate change. Agroforestry has such a high potential because there is a large area that is susceptible for land use change (Verchot et al., 2007). Traditional agroforestry systems, practiced by the majority of farmers in Atacora, are known to be more supportive of biodiversity than monocropping (Schroth, 2004), even though they are not substitute for natural habitat.

Conclusion

Through *in situ* conservation, *V. paradoxa*, agroforests has the potential to contribute to biodiversity conservation in agricultural areas. A total of 41 adult woody species were recorded in *V. paradoxa*'s agroforest, whereas according to land management regimes, 28 species are found in fields and 36 species in fallows. The composition of woody species in Atacora parklands reflects the needs of local communities and their implication in people's livelihood. The results shown in this study suggest the possibility to conserve part of the biodiversity while nourishing the population and reducing its vulnerability to climate change. There is a need to support and maintain this kind of agricultural system, as this exemplifies the synergy for providing, provisioning and supporting services and biodiversity conservation. Moreover, a good understanding of how agroforestry parklands are managed could give insight into sustainable development.

Conflict of interests

The authors did not declare any conflict of interests.

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Appendix 1a. List of woody (fields) species registered in Atacora and their frequency.

Family	Fields species	Richness
Anacardiaceae	*Anacardium occidentale* L.	3
Anacardiaceae	*Lannea acida* A.Rich. s.l.	18
Anacardiaceae	*Lannea microcarpa* Engl. & Krause	11
Anacardiaceae	*Mangifera indica* L.	7
Annonaceae	*Annona senegalensis* Pers. ssp. *oulotrieha* Le Thomas ex Le Thomas	45
Arecaceae	*Borassus aethiopum* Mart.	8
Asclepiadaceae	*Calotropis procera* (Aiton) W.T.Aiton	5
Bignoniaceae	*Stereospermum kunthianum* Cham.	47
Bombacaceae	*Adansonia digitata* L.	6
Bombacaceae	*Bombax costatum* Pellegr. & Vuillet	7
Bombacaceae	*Ceiba pentandra* (L.) Gaertn.	1
Capparaceae	*Crateva adansonii* DC. ssp. *adansonii*	1
Celastraceae	*Maytenus senegalensis* (Lam.)	18
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	9
Combretaceae	*Anogeissus leiocarpa* (De.) Guill. & Perr.	16
Combretaceae	*Combretum collinum* Fresen.	55
Combretaceae	*Combretum glutinosum* Perr. ex De.	14
Combretaceae	*Combretum micranthum* G.Don	17
Combretaceae	*Guiera senegalensis* J.F.Gmel.	2
Combretaceae	*Pteleopsis suberosa* Engl. & Diels	15
Combretaceae	*Terminalia laxijlora* Engl.	31
Connaraceae	*Terminalia macroptera* Guill. & Perr.	7
Ebenaceae	*Diospyros mespiliformis* Hochst. Ex A. De.	31
Euphorbiaceae	*Brideliaferruginea* Benth.	3
Euphorbiaceae	*Flueggea virosa* (Roxb. ex Willd.) Voigt	43
Euphorbiaceae	*Hymenocardia acida* Tul.	2
Leguminosae	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel	13
Leguminosae	*Detarium microcarpum* Guill. & Perr.	6
Leguminosae	*Piliostigma thonningii* (Schumach.) Milne-Redh.	29
Leguminosae	*Tamarindus indica* L.	1
Leguminosae	*Acacia gourmaensis* A.Chev.	3
Leguminosae	*Acacia polyacantha* Willd. ssp. *campylacantha* (Hochst. ex A.Rich.)	39
Leguminosae	*Entada africana* Guill. & Perr.	1
Leguminosae	*Parkia biglobosa* (Jacq.) R.Br. ex Benth.	53
Leguminosae	*Prosopis africana* (Guill. & Perr.) Taub.	7
Leguminosae	*Desmodium velutinum* (Willd.) De.	4
Leguminosae	*Pericopsis laxiflora* (Benth. ex Baker) Meeuwen	3
Leguminosae	*Pterocarpus erinaceus* Poir.	12
Loganiaceae	*Strychnos spinosa* Lam.	8
Meliaceae	*Azadirachta indica* A.Juss.	27
Meliaceae	*Khaya senegalensis* (Desr.) A.Juss.	4
Meliaceae	*Pseudocedrela kotschyi* (Schweinf.) Harms.	4
Meliaceae	*Trichilia emetica* Vahl	2
Moraceae	*Ficus exasperata* Vahl	8
Moraceae	*Ficus ingens* (Miq.) Miq.	4
Moraceae	*Ficus platyphylla* Delile	4
Moraceae	*Ficus sycomorus* L.	23
Moraceae	*Ficus thonningii* Blume	1
Moraceae	*Ficus vallis-choudae* Delile	1
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay	2
Polygalaceae	*Securidaca longepedunculata* Fresen.	1

Appendix 1a. Contd.

Rhamnaceae	*Ziziphus abyssinica* A.Rich.	3
Rubiaceae	*Crossopteryxfebrifuga* (G.Don) Benth.	6
Rubiaceae	*Feretia apodanthera* Delile ssp. *Apodanthera*	15
Rubiaceae	*Gardenia erubescens* Stapf & Huteh.	11
Rubiaceae	*Gardenia ternifolia* Sehumaeh. & Thonn. ssp. *jovis-tonantis* (Welw.) Verde. var. goetzei (Stapf & Huteh.) Verde.	1
Rubiaceae	*Mitragyna inermis* (Willd.) Kuntze	1
Rubiaceae	*Sarcocephalus latifolius* (Sm.) E.A.Bruce	20
Rutaceae	*Zanthoxylum zanthoxyloides* (Lam.) Zepernick & Timler	3
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn. ssp. *Paradoxa*	115
Simaroubaceae	*Hannoa undulata* Planch.	1
Sterculiaceae	*Sterculia setigera* Delile	7
Tiliaceae	*Grewia carpinifolia* Juss.	23
Tiliaceae	*Grewia puhescens* P. Beauv.	10
Verbenaceae	*Tectona grandis* L.f.	1
Verbenaceae	*Vitex doniana* Sweet	20
Verbenaceae	*Vitex madiensis* Olïv. subsp. *madiensis*	1
Vitaceae	*Cissus cornifolia* (Baker) Planeh.	1
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	2

Appendix 1b. List of woody (fallows) species registered in Atacora and their frequency.

Family	Species fallows	Ni
Anacardiaceae	*Anacardium occidentale* L.	4
Anacardiaceae	*Haematostaphis barteri* Hook.f.	2
Anacardiaceae	*Lannea acida* A.Rich. s.l.	21
Anacardiaceae	*Lannea barteri* (Olïv.) Engl.	1
Anacardiaceae	*Lannea microcarpa* Engl. & Krause	11
Anacardiaceae	*Mangifera indica* L.	2
Anacardiaceae	*Sclerocarya birrea* (A.Rich.) Hochst.	5
Annonaceae	*Annona senegalensis* Pers. ssp. *oulotrieha* Le Thomas ex Le Thomas	48
Apiaceae	*Steganotaenia araliacea* Hochst.	2
Araliaceae	*Cussonia arborea* Hoehst. ex A. Rich.	1
Arecaceae	*Borassus aethiopum* Mart.	3
Bignoniaceae	*Stereospermum kunthianum* Cham.	49
Bombacaceae	*Adansonia digitata* L.	1
Bombacaceae	*Bombax costatum* Pellegr. & Vuillet	5
Capparaceae	*Crateva adansonii* DC. ssp. *adansonii*	1
Celastraceae	*Gymnosporia buchananii* Loes.	7
Celastraceae	*Maytenus senegalensis* (Lam.)	20
Chrysobalanaceae	*Parinari curatellifolia* Planch. ex Benth.	6
Combretaceae	*Anogeissus leiocarpa* (De.) Guill. & Perr.	20
Combretaceae	*Cochlospermum planchoni* Hook.f., J.	7
Combretaceae	*Combretum collinum* Fresen.	59
Combretaceae	*Combretum glutinosum* Perr. ex De.	7
Combretaceae	*Combretum micranthum* G.Don	27
Combretaceae	*Guiera senegalensis* J.F.Gmel.	3
Combretaceae	*Pteleopsis suberosa* Engl. & Diels	21
Combretaceae	*Terminalia laxijlora* Engl.	36
Connaraceae	*Terminalia macroptera* Guill. & Perr.	9
Ebenaceae	*Diospyros mespiliformis* Hochst. Ex A. De.	35

Appendix 1b. Contd.

Euphorbiaceae	*Brideliaferruginea* Benth.	9
Euphorbiaceae	*Hymenocardia acida* Tul.	2
Euphorbiaceae	*Flueggea virosa* (Roxb. ex Willd.) Voigt	42
Leguminosae	*Daniellia oliveri* (Rolfe) Hutch. & Dalziel	20
Leguminosae	*Piliostigma thonningii* (Schumach.) Milne-Redh.	41
Leguminosae	*Tamarindus indica* L.	1
Leguminosae	*Acacia amythethophylla* Steud. ex A. Rich.	7
Leguminosae	*Acacia gerrardii* Benth., Trans. Linn.	2
Leguminosae	*Acacia gourmaensis* A.Chev.	8
Leguminosae	*Acacia polyacantha* Willd. ssp. *campylacantha* (Hochst. ex A.Rich.)	44
Leguminosae	*Entada africana* Guill. & Perr.	6
Leguminosae	*Parkia biglobosa* (Jacq.) R.Br. ex Benth.	36
Leguminosae	*Prosopis africana* (Guill. & Perr.) Taub.	6
Leguminosae	*Erythrina sigmoidea* Hua	1
Leguminosae	*Pericopsis laxiflora* (Benth. ex Baker) Meeuwen	2
Leguminosae	*Pterocarpus erinaceus* Poir.	18
Leguminosae	*Aganope stuhlmannii* (Taub.) Adema	1
Loganiaceae	*Strychnos spinosa* Lam.	18
Meliaceae	*Azadirachta indica* A.Juss.	21
Meliaceae	*Khaya senegalensis* (Desr.) A.Juss.	3
Meliaceae	*Pseudocedrela kotschyi* (Schweinf.) Harms.	4
Meliaceae	*Trichilia emetica* Vahl	7
Moraceae	*Antiaris toxicaria* Lesch. ssp. *Welwitschii* (Engl.) C.C.Berg	1
Moraceae	*Ficus exasperata* Vahl	8
Moraceae	*Ficus ingens* (Miq.) Miq.	3
Moraceae	*Ficus sycomorus* L.	13
Myrtaceae	*Eucalyptus camaldulensis* Dehn.	1
Myrtaceae	*Psidium guajava* L	1
Myrtaceae	*Syzygium guineense* (Willd.) DC.	1
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay	2
Polygalaceae	*Securidaca longepedunculata* Fresen.	3
Rhamnaceae	*Ziziphus abyssinica* A.Rich.	10
Rubiaceae	*Crossopteryxfebrifuga* (G.Don) Benth.	17
Rubiaceae	*Feretia apodanthera* Delile ssp. Apodanthera	21
Rubiaceae	*Gardenia aqualla* Stapf & Huteh.	1
Rubiaceae	*Gardenia erubescens* Stapf & Huteh.	20
Rubiaceae	*Gardenia ternifolia* Sehumaeh. & Thonn. ssp.*jovis-tonantis* (Welw.) Verde. var. goetzei (Stapf & Huteh.) Verde.	2
Rubiaceae	*Sarcocephalus latifolius* (Sm.) E.A.Bruce	8
Rutaceae	*Zanthoxylum zanthoxyloides* (Lam.) Zepernick & Timler	1
Sapotaceae	*Vitellaria paradoxa* C.F.Gaertn. ssp. *Paradoxa*	97
Simaroubaceae	*Hannoa undulata* Planch.	1
Sterculiaceae	*Sterculia setigera* Delile	16
Tiliaceae	*Grewia carpinifolia* Juss.	30
Tiliaceae	*Grewia puhescens* P. Beauv.	22
Verbenaceae	*Gmelina arborea* Roxb.	1
Verbenaceae	*Tectona grandis* L.f.	1
Verbenaceae	*Vitex doniana* Sweet	17
Verbenaceae	*Vitex madiensis* Olïv. ssp. *madiensis*	5
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	2
Leguminosae	*Detarium microcarpum* Guill. & Perr.	11

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Status and population trend and status of the common eland in the Kenya – Tanzania borderland: 2010 and 2013 survey analysis

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The common eland is a highly adaptable species and can survive in landscapes where water is scarce. It is listed by International Union for Conservation of Nature (IUCN) as a species of "Least Concern" implying its population is considered to be relatively stable but due to environmental factors changes decline in some populations in range have been documented. In Kenya and Tanzania hunting, habitat loss and fragmentation are key factors contributing to eland population decline but this is exuberated by climate change and wildlife disease. Consequently, this study examined the population status, trend and distribution in the Tanzania-Kenya borderland which experienced a severe and long drought from 2007 to 2009. Eland was common in the entire study area but the Amboseli region had the highest number and density of elands (1,348.50 ± 729.10 individuals; 0.15 ± 0.08 individuals/km^2), followed by Magadi -Namanga area (346.80 ± 220.10 individuals; 0.06 ± 0.03 individuals/km^2), and the least was in West Kilimanjaro (70.80 ± 39.30 individuals; 0.02 ± 0.01 individuals/km^2). In Amboseli and Lake Natron areas, eland density and distribution in landscapes changed more during the wet season; while in Magadi-Namanga and West Kilimanjaro, this was more during the dry season. West Kilimanjaro had the highest percentage increase in eland density (+1850.53) followed by Magadi-Namanga area (+667.76 ± 429.34), and lowest in Amboseli (+88.29 ± 6.19). After the year 2009, the eland population increased more during the wet season in most landscapes except in Lake Natron where they decreased in the dry season. Although the eland was affected by drought, it did not experience a huge decline in its population possibly because of its ecological and behavioral attributes that cushions it from the adverse drought effects.

Key words: borderland, Kenya, population trend and status, Tanzania, Common eland

INTRODUCTION

The Common eland *Tragelaphus oryx* is the largest antelope in Africa (Estes, 2012; Skinner and Chimimba, 2005), and are confined within sub-Saharan Africa with an estimated population of approximately 136,000 individuals as per 2008 (IUCN, 2008). East (1999) produced a total population estimate of 136,000, with stable/increasing national populations now confined to Namibia, Botswana, Zimbabwe, South Africa, Malawi, Kenya and Tanzania. Population trends vary from increasing to decreasing within individual protected areas, and are generally increasing on private land and decreasing in other areas. However, this population is far much less compared to estimates of the 1970s (over half a million then), but the IUCN has listed it as a species of "Least Concern" (IUCN, 2008).

The species inhabits diverse habitat types including Acacia savanna, alpine moorlands of up to 4,900 m above sea level, sub-deserts and Miombo woodlands (IUCN, 2008), and this is attributed to their ability to use a variety of food resources and to survival with little or no water (Skinner and Chimimba, 2005). They also use open plains but avoid dense vegetation types like forests (Pappas, 2002), and are mostly browsers, and feed on foliage but also other food items like seeds, tubers, succulent fruits and flowers (Skinner and Chimimba, 2005). During the wet season, they are likely to graze but tend to forage on high quality newly sprouted grasses (Pappas, 2002), but generally, they tend to select food based on its fiber content which is a function of the leaf stem ratio (Owen-Smith, 2002). Unlike most of the closest relatives, the common eland is quite nomadic and extremely gregarious and can form large herds of up to 500 individuals but are no-territorial (Estes, 2012; Pappas, 2002; La Grange, 2006).

In Kenya, the eland is still common in its former range (southern, central and northwestern) but the population is decreasing (East, 1999), and major populations are located outside protected areas in Kajiado, Narok and Laikipia where their numbers are considered to be stable. The largest protected area population was found inside and around Tsavo National Parks but declined rapidly from approximately 9,960 animals in 1991 to 760 in 1997, due to drought, rinder pest and increasing competition for food resources from livestock (East, 1999). Smaller but protected populations occur in areas like Meru, Nairobi, Amboseli and Aberdare National Parks (East, 1999). Some studies have shown a decline in the common eland population is some parts of the country such as in the Maasai-Mara ecosystem where over 76% decline between 1977 and 1997 (Ottichilo et al., 2000), and in the Athi-Kaputei ecosystem between 2006 and 2011 (Ogutu et al., 2013). These studies attribute this decline to a combination of factors such as land use changes, habitat loss and fragmentation, drought and forage completion with livestock. In Tanzania, the species is still common in savanna woodlands and grasslands especially in the Serengeti National Park, Katavi, Ruaha-Rungwa and Selous-Kilombero (East, 1999). Nevertheless, it has rapidly declined or disappeared in the small sized protected areas like Biharamulo Game Reserve and Ngorongoro Crater due to increased environment degradation and the insular effects created by such small protected areas on such a highly mobile species with a large home range requirement (East, 1999).

Throughout their range, the common eland faces numerous threats all of which have contributed to reduction in their population. Hunting and habitat loss due to expanding human settlements and infrastructure development are considered to be major contributors to this decline (East, 1999; Ottichilo et al., 2000; IUCN, 2008; Ogutu et al., 2013). The species is also prone to a variety of diseases including; foot-and-mouth, tuberculosis and roundworms (Bothma et al., 2002), and these can negatively affect their population performance. Climate variability especially prevalence of droughts is a major factor responsible for abrupt extermination of large populations of animal over wide areas (Ottichilo et al., 2000; Ogutu et al. 2013). For instance, in Kenya's rangelands, the 2000 severe drought caused high mortality and decline in the population of large herbivores (wildlife and livestock) including a shift in their normal distribution pattern (Ogutu et al., 2013). Ecologically, drought leads to reduction in availability of forage and water resources which in turn become limiting factors to wildlife and livestock due to starvation. Although the Common eland can survive without frequent access to water because they can obtain enough moisture from their food (Estes, 2012; IUCN, 2008), its survival is still at risk due to increased mortality during droughts (Pappas, 2002; Skinner and Chimimba, 2005). The ongoing land use and land tenure changes, increase in human population and the resultant development in the Northern Tanzania and Southern Kenya borderland are likely to compound the threat posed by climate change to the Common eland population.

Between 2007 and 2009, the Southern Kenya and Northern Tanzania borderland experienced a severe drought which saw both wildlife and livestock die in large numbers. This study was therefore conducted in the wet and dry seasons of 2010 and 2013 to evaluate the population status and distribution of the Common eland in the region. Specific objectives were to 1) Determine the population status and trend of Common eland in the borderland; 2) assess spatial-temporal distribution of Common eland in the Kenya-Tanzania borderland; 3) make recommendations to enhance monitoring and conservation of wildlife populations across the borderland

MATERIALS AND METHODS

Study area

The Southern Kenya region comprises of Amboseli National Park,

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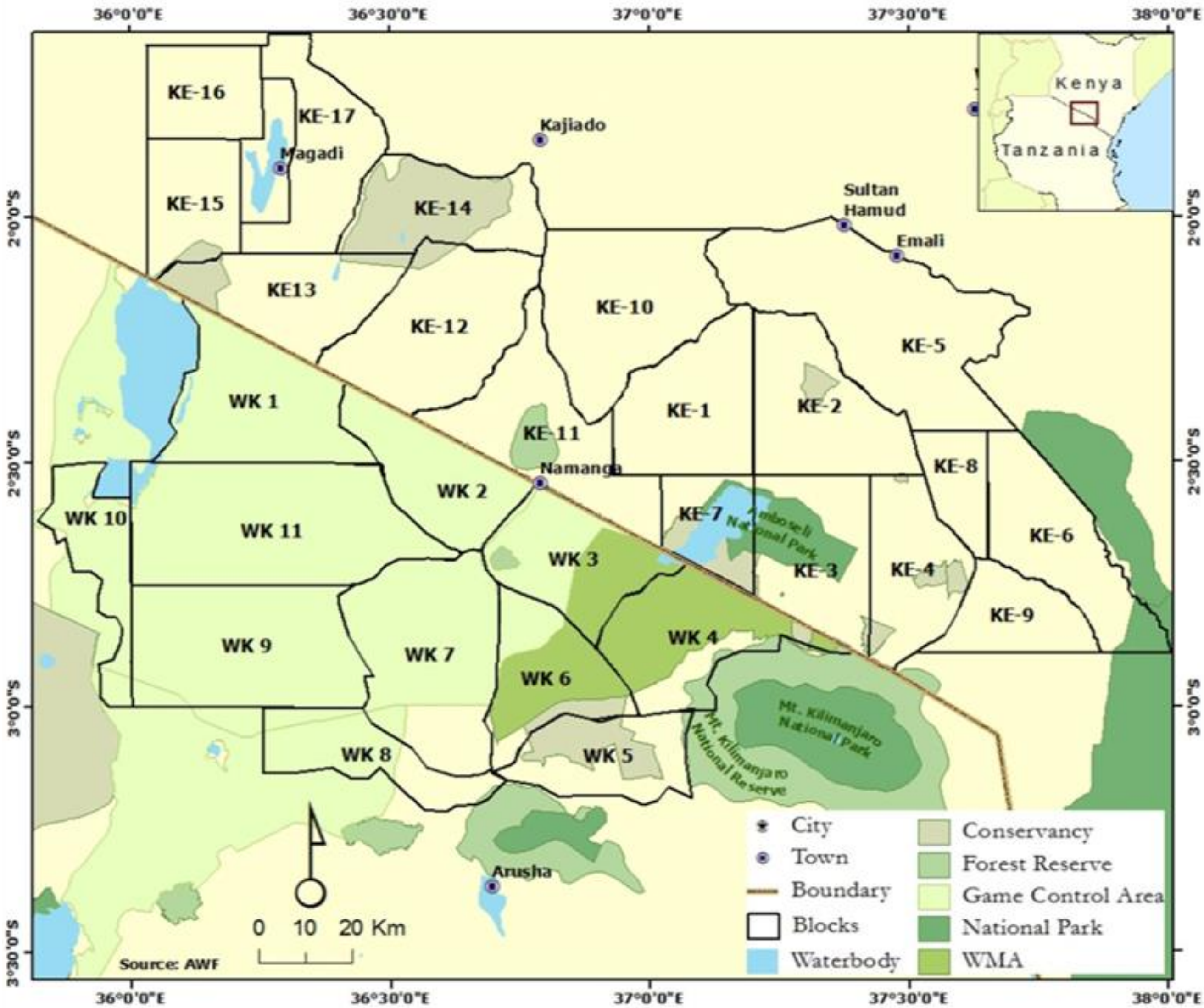

Figure 1. The Amboseli-West Kilimanjaro and Magadi - Natron landscapes along the Kenya-Tanzania borderland. Source: Kenya Wildlife Service and Tanzania Wildlife Research Institute 2013.

adjoining Maasai group ranches and private lands in the Oloitokitok area along the Kenya-Tanzania border, Namanga, Magadi and Nguruman in the southern part of Kajiado County approximately 8797 Km^2, (Figure 1). On the Tanzania side, it is made up of the Natron and West Kilimanjaro landscapes, and the entire borderland covers an area of >25,000 Km^2. The region has in the recent past experienced a rapid increase in human population particularly in the group ranches and along the slopes of Mt. Kilimanjaro (Ntiati, 2002; Reid et al., 2004; Okello and D'Amour, 2008). Further, it has also experienced widespread land use changes over the past 30 years in response to a variety of economic, cultural, political, institutional, and demographic processes (Reid et al., 2004). Pastoralism is mostly practiced by the predominantly Maasai people in the borderland has continued to decline forcing the community to turn to farming like other ethnic groups (Ntiati, 2002; Okello, 2005; Okello and D'Amour, 2008).

Most of the Amboseli region is classified as ecological zone VI and is characterized by a semi-arid environment, with most of it being suitable for pastoralism and wildlife conservation (Pratt and Gwynne, 1977). It has a bimodal rainfall pattern but the average annual rainfall is quite low ranging between 400 to 1000 mm (Reid et al., 2004). The long rains are normally received at the beginning of the year (between March and May) while the short rains occur at the end of the year (end of October and mid-December) (Western, 1975; Okello and D'Amour, 2008). Thus, rainfall is the key determinant of land use practices in the entire region (Ntiati, 2002; Okello, 2005). Surface water availability is sparse and the hydrology is mostly influenced by Mt. Kilimanjaro. Generally, vegetation of the region is typical of a semi-arid environment, with some of the dominant vegetation communities being; open grasslands, Acacia dominated bushland and the forest belt of Mt. Kilimanjaro, interspersed with patches of swamps-edge grasslands, Acacia woodlands and swamps (Croze and Lindsay, 2011).

The Namanga-Magadi covers an area of > 5, 000 Km^2 most of which comprise of Maasai group ranches (Figure 1). Like other parts of the borderland, it is a semi-arid environment with little rainfall of between 400 - 600 mm, which is bimodal and highly variable and these conditions make it suitable for wildlife

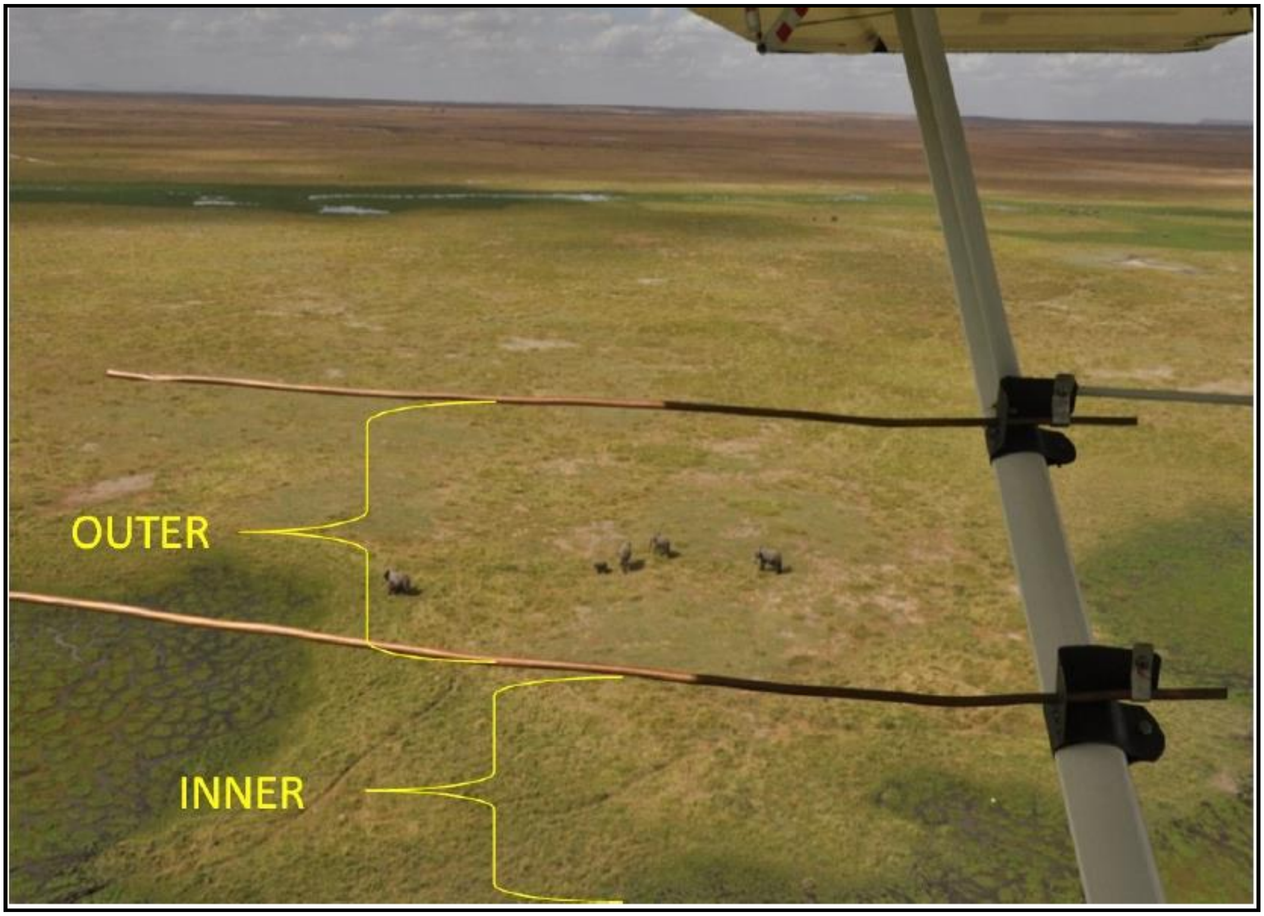

Figure 2. Layout of the streamers attached to the aircraft so as to define the area under the ground that elands were counted. Source: Kenya Wildlife Service and Tanzania Wildlife Research Institute 2013.

conservation and pastoralism (Kioko, 2008). In a few areas, mostly along the Maili-Tisa-Namanga road, the main rivers and Ewaso Nyiro, the locals usually carry out limited irrigated agriculture. There is spatial-temporal variation in vegetation types in response to variation in the landscape and elevation. Due to the semi-arid nature of the region, the soils are poorly developed but are mainly "black clayey" (grumosolic soils) comprising of a variety of "black cotton" soils including the calcareous and non-calcareous variants. Ewaso Nyiro River is the main water sources although there are several seasonal rivers like the Namanga, Ol Kejuado and Esokota.

Lake Natron area lies west of the West Kilimanjaro area, and its northern part is defined by the Tanzania-Kenya border, with a total area of approximately 7,047 Km^2), (Figure 1). It's largely a semiarid savannah interspersed with open acacia woodlands (Acacia spp. and Commiphora spp.). The southern boundary extends from the southeast corner of Ngorongoro Conservation Area eastward to the northwest corner of Arusha National Park, while the western part is situated along the eastern side of Lake Natron to Ngorongoro Conservation area. Similar to other landscapes of the borderland, rainfall is low (<350mm/year), and is highly variable and largely unpredictable. The vegetation types are very diverse and therefore provide expansive livestock grazing land.

The West Kilimanjaro is found in the Longido District, and its northern sector lies along the Kenya-Tanzania border from Namanga southeastward to Irkaswa covering >3000 Km^2 (Figure 1). Annual rainfall varies depending on the elevation, with the semi-arid lower elevations receiving 341 mm/year and lower elevations on Mt. Kilimanjaro at Mt. Meru and Monduli in the south receiving part 890 mm/year (Moss, 2001). Nevertheless, it is generally variable and unpredictable. In terms of vegetation, the region has a complex and heterogeneous vegetation community with extensive swathes of farming and grazing lands. The dominant inhabitants are the Maasai people who have over the years tuned into agro-pastoralists. Numerous wildlife conservation areas are found in the region like Kilimanjaro National Park (755 Km^2), Arusha N. P (137 Km^2, Longido Game Controlled Area (GCA) (1,700 Km^2) and Ngasurai Open Area (544 Km^2).

Methods and analysis

Eleven (11) and seventeen (17) blocks were delineated on the Tanzania and Kenya side respectively (Figure 1) in which trained wildlife biologists carried out a total aerial count of the Common eland in the wet (March) and dry (October) season of 2010 and 2013 (May, wet season and October, dry season) as described by Norton-Griffiths (1978). Aircrafts used in the counts were fitted with steamers on either side of the wings (Figure 2), and the field of vision of the streamers calibrated using mock flights as outlined by Ottichilo and Sinange (1985). Experienced and well trained flights rear observers then counted the number of Common eland appearing between the rods of the streamers (Dirschl et al., 1981) along 5 Km transect segments. The width of the count transects varied from 1-2 Km, with a North to South orientation and East to

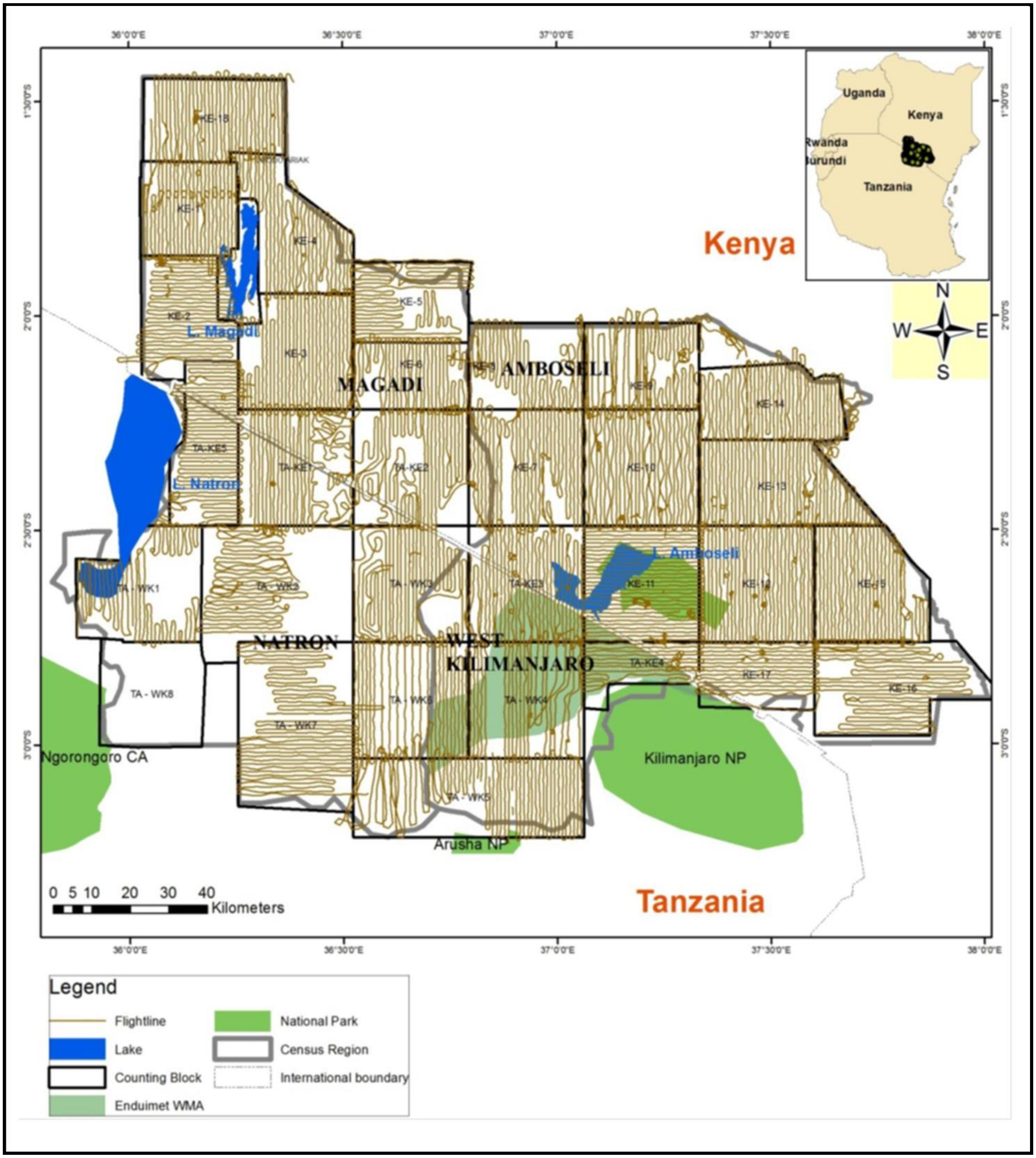

Figure 3. Layout of the census flight paths and flights direction used for the data collection in the study area. *Source*: Kenya Wildlife Service and Tanzania Wildlife Research Institute 2013

West direction depending on the degree of ground visibility and nature of the terrain (Figure 3). The average speed of the aircraft was 156 Kmph, and at a mean elevation of 383.8 ± 251ft above the ground. A single day was taken to cover the area with several aircrafts covering a single block so that it was accomplished in a single survey.

During the flight, the observers recorded the count data on tape recorders and data sheets. The coordinates of all the elands observed were taken using a GPS and in instances whenever more than ten individuals were encountered in a group, a photograph was taken and their correct tally verified later. A DNR-Garmin/Map Source software was used to download the GPS coordinates after

Table 1. Eland numbers and density in the key population hotspots of the Kenya / Tanzania borderland.

Location	Year	Season	Census area (km^2)	Eland numbers	Eland density (per km^2)	Eland (%) of numbers in the borderland
Amboseli and surrounding group ranches	2010	Wet	8797.00	1621	0.18	81.38
		Dry	8797.00	162	0.02	65.59
	2013	Wet	9214.44	3302	0.36	65.58
		Dry	9214.44	309	0.03	48.97
	Mean ± SE		-	1,348.5 ± 729.1	0.15 ± 0.08	65.38 ± 6.62
Magadi /Namanga Areas	2010	Wet	5513.00	247	0.04	12.40
		Dry	5513.00	10	0.00	4.05
	2013	Wet	6348.32	991	0.16	19.68
		Dry	63.48.32	139	0.02	22.03
	Mean ± SE		-	346.8 ± 220.1	0.06 ± 0.03	14.54 ± 4.05
West Kilimanjaro Area	2010	Wet	3014.00	0	0.00	0.00
		Dry	3014.00	8	0.00	3.24
	2013	Wet	3013.18	119	0.04	2.36
		Dry	3013.18	156	0.05	24.72
	Mean ± SE		-	70.8 ± 39.3	0.02 ± 0.01	7.58 ± 5.75
Lake Natron Area	2010	Wet	7047.00	124	0.02	6.22
		Dry	7047.00	67	0.01	27.13
		Wet	7047.26	623	0.09	12.37
	2013	Dry	7047.26	27	0.00	4.28
	Mean ± SE		-	210.3 ± 139.0	0.03 ± 0.02	12.50 ± 5.17

which spatial distribution maps were created using ArcGIS 9.2 program. Statistical Package for Social Sciences (SPSS, 2011) version 20.0 (SPSS Inc., Chicago, Illinois, USA) was used to spartially analyze the data collected.

Population changes of the common eland were calculated using density estimates of 2013 and how they varied from 2010 for each season. Using the SPPS software, Chi – square goodness of fit and Chi – square cross – tabulations tests were also used to establish any differences and associations between eland numbers (across seasons and years) among various landscapes in the borderland region (Zar, 1999). For each test, Statistical tests were considered significant if type 1 error (alpha) was less than 5% (0.05) (Zar, 1999). Given that the census areas (for both wet and dry season) for 2010 and 2013 was the same, comparisons of the total numbers, density and percentages (proportions) of eland were considered appropriate.

RESULTS

Common eland was well represented in all the landscapes and ecosystems (protected areas and dispersal areas) along the Kenya – Tanzania borderland during the 2010 and 2013 censuses. Amboseli and its surrounding group ranches had the highest number of eland (Table 1) in the borderland (averaging 1,348.5 ± 729.1 eland), followed by a distant Magadi / Namanga area (346.8 ± 220.1 eland), Lake Natron area (210.3 ± 139.0 eland), and lastly West Kilimanjaro area (70.8 ± 39.3 eland).

In terms of the distribution of elands in the landscapes, eland in each area of the borderland (Figure 4), similar order was seen, with Amboseli and surrounding group ranches leading (65.38 ± 6.62%) followed by Magadi / Namanga area (14.54 ± 4.05%), Lake Natron area (12.50 ± 3.86%), and lastly West Kilimanjaro (5.57 ± 2.60%). For eland density (Figure 5), Amboseli area had also the highest eland density (Table 1) averaging 0.15 ± 0.08 eland (per km^2), followed by Magadi / Namanga area (0.06 ± 0.03 eland per km^2), Lake Natron area (0.03 ± 0.02 eland per km^2), and lastly West Kilimanjaro area (0.02 ± 0.01 eland per km^2).

Considering (percent) changes in the density in each of the locations of the borderland between 2010 and 2013, West Kilimanjaro area had the highest positive average percent change (increase) in eland density (+1850.00 (which occurred in the dry season) compared to other locations in the borderland (Table 2). The positive growth in eland density was also seen in Magadi / Namanga area (+667.76 ± 429.34). The next positive increase in density occurred in Lake Natron area (+171.35 ± 231.05), but with high variability in the change because of negative growth in the dry season. Amboseli and surrounding group ranches had the lowest change in eland density (+88.29 ± 6.19) but without any negative (decline) change in eland numbers. All the changes in each season were positive for all locations (except dry season in Lake Natron area) implying a general increase in the eland density over time (Table 2).

Considering (percent) changes in the eland numbers in

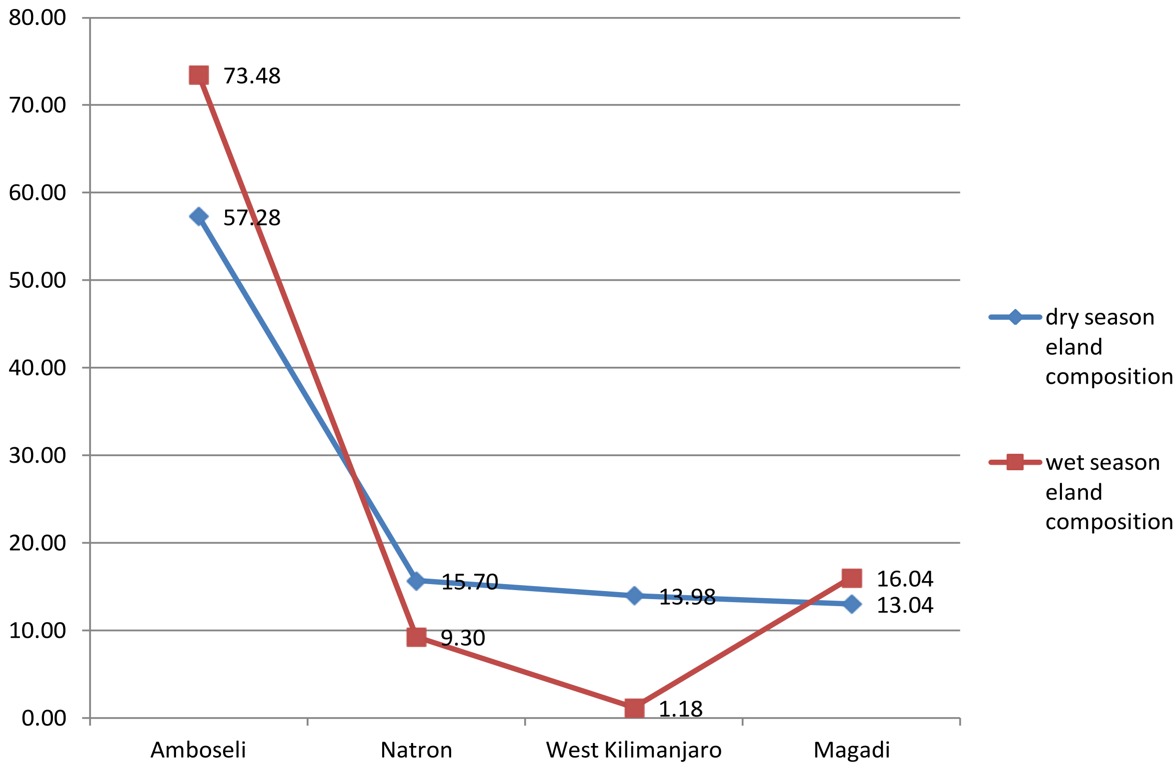

Figure 4. Eland distribution (% of numbers) in the wet and dry season in various landscapes of the Kenya - Tanzania borderland ecosystem.

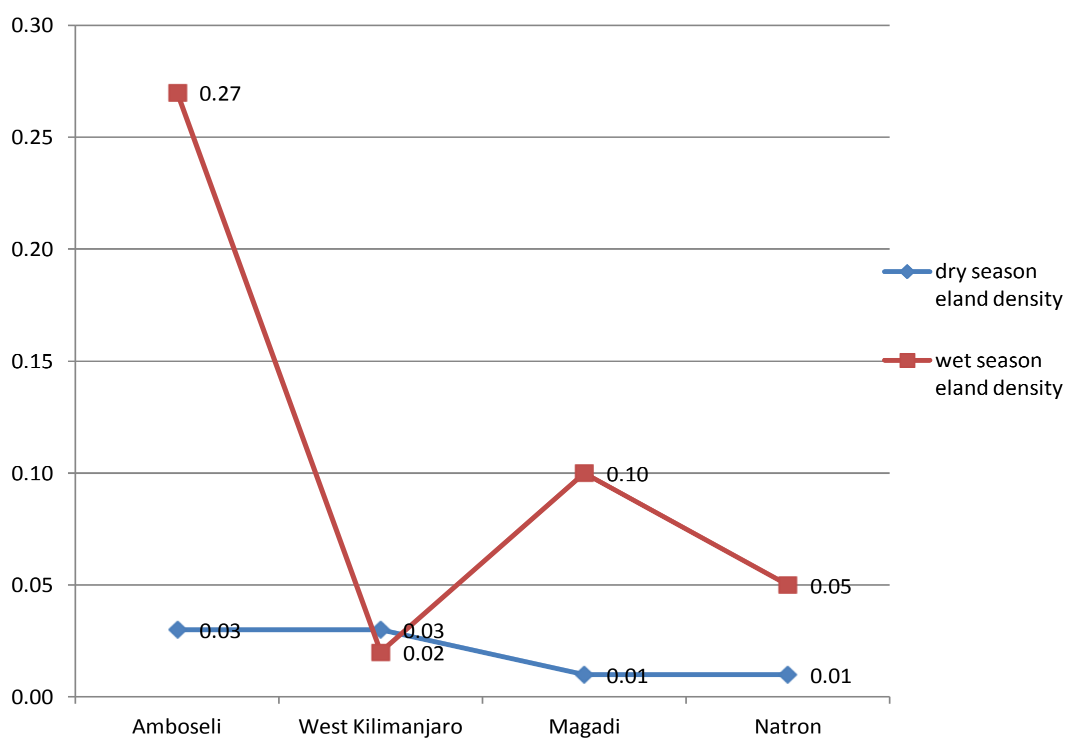

Figure 5. Eland densities (animals per km^2) in the wet and dry season in the Kenya -Tanzania borderland ecosystem.

Table 2. Eland numbers and density changes in wet and dry seasons between 2010 and 2013.

Location	Season	Eland density (per km^2) (mean ± SE)	Eland % numbers in location (mean ± SE)	Change (%) in eland density over 3 years	Eland (%) of numbers in the borderland
Amboseli and surrounding group ranches	Wet	0.27 ± 0.09	73.48 ± 7.90	+ 94.47	+ 103.70
	Dry	0.03 ± 0.01	57.28 ± 8.31	+ 82.10	+ 90.74
	Mean ± SE	0.15 ± 0.08	65.38 ± 6.62	+88.29 ± 6.19	+97.22 ± 6.48
Magadi and Namanga Areas	Wet	0.10 ± 0.06	16.04 ± 3.69	+248.42	+ 301.21
	Dry	0.06 ± 0.03	13.04 ± 8.99	+ 1107.10	+ 1290.00
	Mean ±SE	0.01 ± 0.00	14.54 ± 4.05	+ 677.76 ± 429.34	+975.61 ± 494.39
West Kilimanjaro Area	Wet	0.02 ± 0.02	1.18 ± 1.18	No animals seen in wet season 2010	No animals seen in wet season 2010
	Dry	0.03 ± 0.02	13.98 ± 10.74	+ 1850.00	+ 1850.53
	Mean ± SE	0.05 ± 0.04	7.58 ± 5.75	-	-
Lake Natron Area	Wet	0.01 ± 0.00	9.30 ± 3.07	+ 402.40	+ 402.42
	Dry	0.02 ± 0.00	15.70 ± 11.42	- 59.70	- 59.70
	Overall	0.03 ± 0.02	12.50 ± 5.17	+171.35 ± 231.05	+171.36 ± 231.06

each of the locations of the borderland, West Kilimanjaro area had also the highest positive (percent) change (increase) in eland numbers (+1850.53 (which occurred in the dry season) compared to other locations in the borderland (Table 2). The positive growth in eland number was next seen in Magadi / Namanga area (+975.61 ± 494.39). The next positive increase in eland numbers occurred in Lake Natron area (+171.36 ± 231.06), but with high variability in the change because of negative growth in the dry season. Amboseli and surrounding group ranches had also the lowest change in eland numbers (+97.22 ± 6.48) but without any negative (decline) change in eland numbers. All the changes in each season were positive for all locations (except dry season in Lake Natron area) implying a general increase in the eland numbers over time (Table 2).

There were more changes in eland density and composition in the wet season in Amboseli and Lake Natron areas, but more changes in the dry season in West Kilimanjaro and Magadi areas. The highest change differences in both density and composition were in West Kilimanjaro, Magadi, Lake Natron area and lastly Amboseli area. A decline (negative change) in eland density and numbers was only seen in the dry season and only in the Lake Natron area (Table 2).

For Amboseli area, both 2010 and 2013, wet season number was higher ($p < 0.001$) than dry season number (Table 3). Further, eland numbers were increasing over time with both wet and dry season of 2013 higher ($p < 0.001$ in both cases) than for 2010 (that is eland number increased with time). For Magadi / Namanga area, both 2010 and 2013 wet season number was higher ($p < 0.001$) than dry season number. Further, eland numbers increased over time with both wet and dry season of 2013 higher ($p < 0.001$ in both cases) than for 2010 (Table 3).

For West Kilimanjaro area, elands were seen only in the dry season of 2010 and not the wet season of 2010. However, for 2013, wet season number was higher ($p < 0.001$) than dry season number (Table 3). Further, eland numbers increased over time with wet and dry season of 2013 being higher ($p < 0.001$ in both cases) than for 2010 (Table 3).

For Lake Natron area both, 2010 and 2013 wet season number was higher ($p < 0.001$) than dry season number (Table 3). For the set of wet season, eland number was higher ($p < 0.001$) in 2013 than 2010 (eland number was increasing with time in the wet season). However, for the set of dry season, eland number declined, with dry season of 2010 numbers being higher ($p < 0.001$) than in 2013 (Table 3).

In terms of relationships between eland numbers in different locations, influence of seasons on eland numbers varied among the locations in the borderland depeding on wither they were inside and round protected area (Amboseli and West Kilimanjaro) or entirely in the dispersal areas away from protected areas (Lake Magadi and Lake Natron) (Table 4). In general, eland population number in the different landscapes was independent ($X^2 = 0.13$, df = 1, $p = 0.72$) of the season, with numbers across various landscapes being similar across seasons. Specifically, in the wet season, eland number in various landscapes was dependent ($p < 0.001$) on year, with numbers increasing with time. However, in the dry season, eland numbers in various landscapes was independent ($p = 0.15$) of year, with numbers remaining similar over time.

Even though the eland was widely distributed, they seemed to cluster in groups across the borderland in the dry season (Figure 6), while in the wet season, they dispersed much more (Figure 7).

DISCUSSION

The Common eland is relatively well represented both in

Table 3. Eland number comparisons between seasons and within seasons in various landscapes within the Kenya – Tanzania borderland.

Census location	Year	Season census done		Chi – square goodness of fit value
		Wet season	Dry season	
Amboseli	2010	1621	162	X^2 = 1193.88, df = 1, p < 0.001
	2013	3302	309	X^2 = 2480.77, df = 1, p < 0.001
	Chi – square value	X^2 = 573.99, df = 1, p < 0.001	X^2 = 45.88, df = 1, p < 0.001	
Magadi	2010	247	10	X^2 =218.56, df = 1, p < 0.001
	2013	991	139	X^2 = 642.39, df = 1, p < 0.001
	Chi – square value	X^2 = 447.12, df = 1, p < 0.001	X^2 =111.69, df = 1, p < 0.001	
West Kilimanjaro	2010	No elands seen	8	Test not necessary
	2013	119	56	X^2 = 22.68, df = 1, p < 0.001
	Chi – square value	Test not necessary	X^2 = 36.00, df = 1, p < 0.001	
Natron	2010	124	67	X^2 = 17.01, df = 1, p < 0.001
	2013	623	27	X^2 = 546.49, df = 1, p < 0.001
	Chi – square value	X^2 =333.33, df = 1, p < 0.001	X^2 = 17.02, df = 1, p < 0.001	

Table 4. The relationship between Eland numbers in different within parks (Amboseli and west Kilimanjaro) and outside (Magadi and Lake Natron) across the seasons in the borderland landscapes.

Season of the year	Year	Location of census area in the landscape in regards to protection		Chi – square cross tabulation value
		In and around protected areas	Outside protected areas	
Wet season	2010 (after drought)	1621	371	X^2 = 127.03, df = 1, p < 0.001
	2013 (post drought)	3421	1614	
Dry season	2010 (after drought)	170	77	X^2 = 2.10, df = 1, p = 0.15
	2013 (post drought)	465	166	
Overall for season across years	Wet season	5042	1985	X^2 = 0.13, df = 1, p =0.72
	Dry season	635	243	

distribution and numbers in the borderland, but with all other species from census in Amboseli, West Kilimanjaro, Lake Natron and Magadi / Magadi area, the bulk of the species is in the Amboseli Ecosystem (Okello et al., 2015a, b). This, as with the conservation of other large mammals in these areas of the borderland, Amboseli area remains a very important hub for their conservation, and likely a source of dispersing individuals to the other ecosystems in the borderland. However, the distribution showed clumped nature in the locations where the eland was found. This is not unusual and is consistent with the social and grouping behavior of the elands. Elands can form very large herds than most bovids, with an example of about 500 individuals in one place in the Serengeti (Estes, 2012). Since eland density overall is often less than 1 eland per km^2, their distribution can be unusually clumped, but this also depends on habitat quality and season (East, 1999). However, the clumped distribution in small areas in the borderland can likely serious general decline in these species due isolation, but this eventuality is corrected for by the highly mobile nature of the elands, allowing it to reach other groups and mate.

Even though the bulk of the elands were found in Amboseli, other locations (led by Magadi / Namanga, Natron and West Kilimanjaro respectively) had eland presence. This indicates that these ecosystems are still

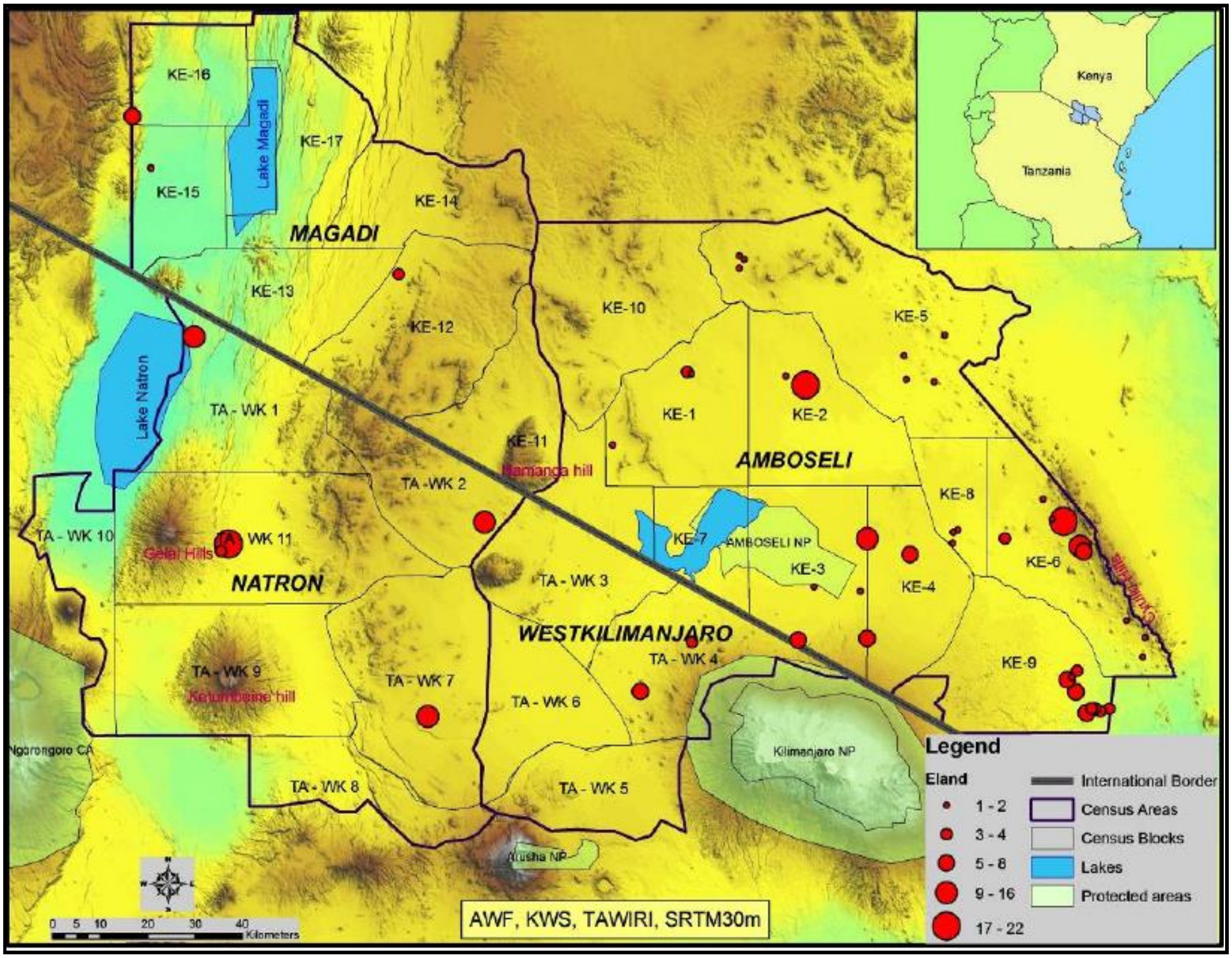

Figure 6. Eland distribution in the Kenya -Tanzania borderland during the 2010 dry season census.

important habitats and ranging lands for the elands on the borderland. But more important is when you examine the rate of density and number changes over time and across seasons. Amboseli had the least positive (growth) change in the number and density of elands, possibly because it had many elands already, and may be reaching a potential carrying capacity for eland given that it shares that range with a host of other wild herbivores and livestock. Natron, with a negative (decline) growth in eland numbers and density in the dry season, could have had its eland population dying of natural mortality, poached, or illegally or simply moved to other locations (most likely because of their high mobility and adaptable nature). But the fact that high positive changes occurred, the three other landscapes other than Amboseli area (West Kilimanjaro and Magadi / Namanga areas in particular) points the fact that elands may have moved in (colonized this area) or multiplied. This implies that these areas are important range for elands, and that they can be colonized by eland populations (moving from elsewhere such as Amboseli) and with a potential to build its own sizeable and viable eland populations. Elands increased with time and generally had higher wet season numbers than dry season numbers in several locations except in Lake Natron where they decreased with time in the dry season. Further, even though there were no elands in West Kilimanjaro in wet season (March) 2010, they were present in later in subsequent counts implying they moved out during the drought in search of better forage and water, but moved back (recolonized) the area after the droughts (dry season October 2010). Eland numbers in locations were independent of season, and numbers were similar near and inside protected areas as with landscapes further that were not protected areas. This may seem odd as we expect that generally it will be higher inside and near protected areas; and also that herbivore numbers will depend on season in which numbers will increase in the wet than dry season. These

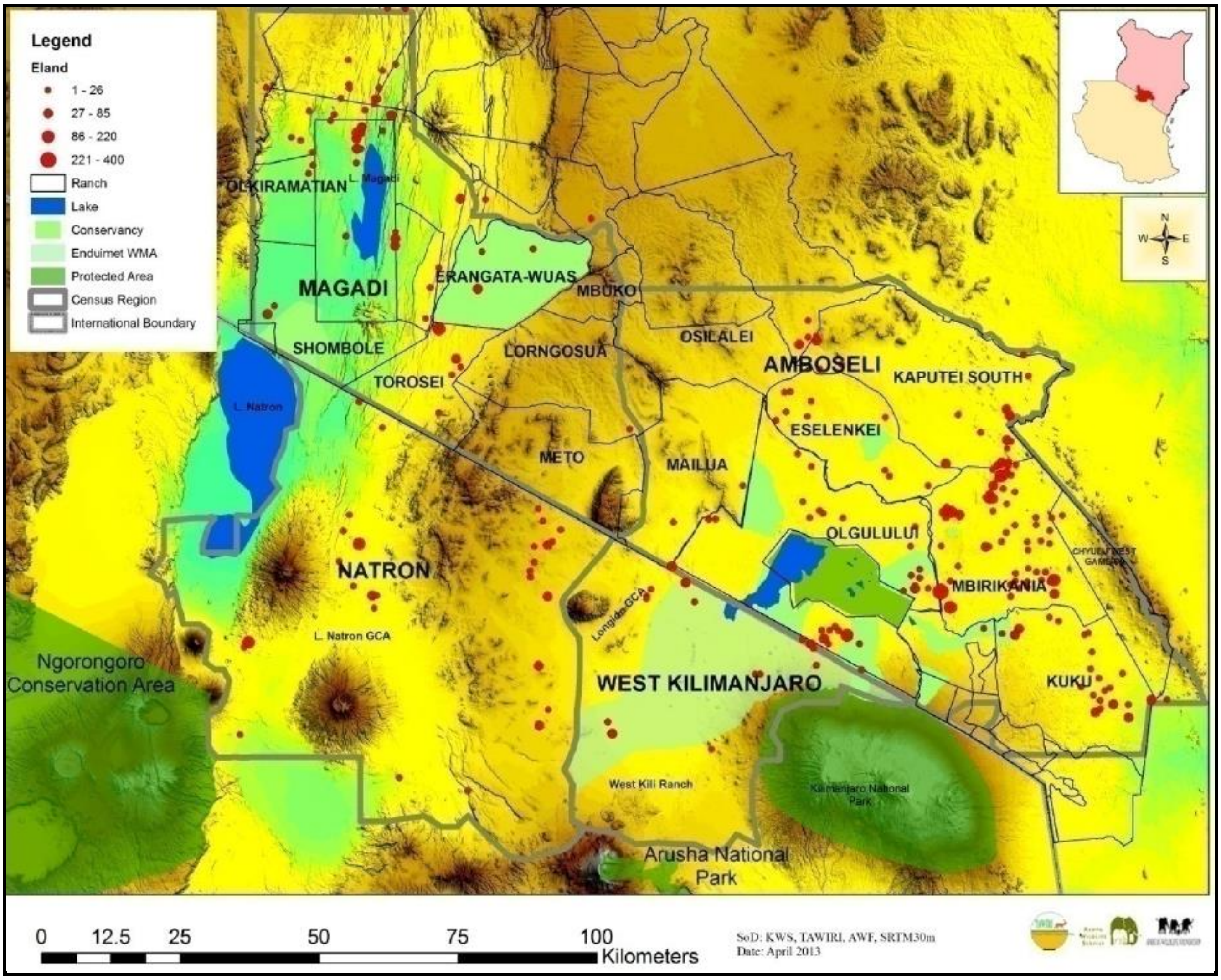

Figure 7. Eland distribution in the Kenya -Tanzania borderland during the 2013 wet season census.

can be explained by the high mobility, highly adaptable foraging behavior and ability for elands to go for long without drinking water (Estes, 2012).

Both frequent and long distance movements as well as mixed feeding (on grass and leaves) afford them the ability to move long areas searching for forage and water and hence they will be less confined by the seasons and its influence on distribution of forage and water. Therefore, elands are able to escape the limitations of the dry season and droughts and minimize mortality and impacts on its population size through this movements and adaptive foraging strategies. This could also explain why elands in the borderland have maintained quite good population size following the droughts of 2007 and 2009 which greatly increased dry season mortality and reduced population numbers of other herbivores in the borderland.

The eland is one of the most adaptable antelopes (Estes, 2012). It moves long distances utilizing resource in broad habitat use such as in acacia open lands as well as in woodlands and bushlands, but avoiding dense forests (Estes, 2012). In the dry season, they range widely seeking fresh forage (leaves and green grass) but also fruits, pods, seeds, herbs and tubers as an adaptable selective mixed feeder (Estes, 2012). This broad and extremely varied diet allows it to achieve its high tolerance of habitats types and make it one of the most adaptable mixed feeders. As it moves, it seeks to conserve water through both behavioral and through body metabolism process. When water becomes very scarce, elands allow their body temperatures to rise as high as 7°C above the body temperature during the day in anticipation of cooler night time to cool them again. Their large body size keeps the temperatures from rising much faster than it would do in other similarly adopted species like Oryx and gazelle, and hence allow them to store more heat and release it when temperatures cool in evenings or night time, by feeding more at night and late in the morning, and by seeking shade in the heat of the day. This reduces water loss by evaporative cooling (Estes, 2012; Estes, 2012, East, 1999).

The number of elands in and around protected areas and in unprotected landscapes was independent of the year (time) in the dry season, but was dependent on year (time) in the wet season. This relationship is also affected by the ability of elands to be adaptable on forage, stay for long without drinking free running water, and long movements it makes over the landscapes. We generally expect that eland numbers will increase in any location in the wet season because of plenty of forage and water, and that these conditions may also lead to new births which may coincide with this plentiful of resources necessary for its survival. Indeed mating and birth for elands occur most of the year, but definite peaks in births occur late in the dry season and early in the rainy season (Estes, 2012; East, 1999). We therefore expect, with new births (and immigrations if necessary) increase in eland populations over time, but specifically during the wet season. This explains why eland numbers were dependent on time (year) in the wet season because of the enhanced reproduction and hence new individuals in the population. For the dry season, eland numbers will be independent because eland will move from one place to another, sometimes in long distances as they seek suitable forage and water consistent with its adaptability and mobility abilities.

The finding that eland population was increasing with time after the 2007 and 2009 droughts mean that they were on the way to full recovery in the borderland. But even though this is positive population trend, it is likely that this buildup will remain localized to suitable habitats and where these species are safe from impacts of people such as human encroachment, poaching by bushmeat and habitat destruction. Management attention should be focused on Lake Natron and Magadi / Namanga areas of the borderland because they had lowest numbers and recovery rate of these species. With increasing eland numbers in the wet season, and with time, there is great potential and opportunity to get the numbers build up again and become viable populations in all landscapes that form the borderland Meta - population.

Lastly, the safety of eland and other large mammal species in the borderland is critical for allowing for re - colonization of the space where wildlife large mammals in the borderland can again live after the droughts. Reduced conflicts with wild herbivores over damages (may be due to crop raiding and in some cases competition for water, pasture and space), and threats (such as bush meat poaching) and habitat destruction will lead to a steady large herbivore decline in the borderland. We need to establish what other human - induced mortality has led to a decline of these four species and take remedial action. In this regard, continued cross border collaborative management and population monitoring (between Kenya and Tanzania) is very essential. Further, joint effort in ground population monitoring and undertaking anti – poaching that allow positive population growth and dispersal of large wild mammals in the borderland landscape will enhance the new legal obligations of countries in cross border conservation collaboration in East Africa.

Conflict of interests

The authors did not declare any conflict of interest.

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Full Length Research Paper

The status of key large mammals in the Kenya – Tanzania borderland: A comparative analysis and conservation implications

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Wildlife populations in Africa are declining rapidly because of natural and human – induced causes. Large animal aerial counts were done in 2010 and 2013 wet and dry season in Mid Kenya/ Tanzania borderland. These counts came after the severe droughts of 2007 and 2010 and so they were critical also in establishing the effects of droughts on large mammal populations. Of the 15 common large mammals seen in the borderland, the five most abundant large wild mammals were the common zebra, common wildebeest, Grants gazelle, the Maasai giraffe, and the common eland respectively but the five rare were the common waterbuck, the common warthog, the lesser kudu, gerenuk, and the olive baboon. Based on the numbers and rate of decline, species of conservation concern were common waterbuck, olive baboon, buffalo, common warthog, lesser kudu and African elephant respectively. Elephant numbers in Amboseli stood at 1,145, much higher than Magadi / Namanga (69), West Kilimanjaro (67) and Lake Natron area (27) of the estimated 1,308 in the borderland. Amboseli area led in numbers, proportion and density, but had the lowest values on population growth. It is recommended that species that are declining have focused conservation action. For West Kilimanjaro and Lake Natron area, poaching and habitat degradation should be addressed. Consistent cross border monitoring should continue to animal establish trends and performance of ecosystems in the borderland.

Key words: Amboseli, effect of droughts, Lake Natron, Magadi / Namanga, West Kilimanjaro, Wildlife status and trends.

INTRODUCTION

Wildlife conservation in Kenya - Tanzania borderland began during the British colonial rule and continued after independence in 1963 (Norton-Griffiths, 1978). This has seen nearly 8% of the country set aside for biodiversity

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conservation purposes (Kenya Wildlife Service, 1994), and plans are underway to have additional landscapes designed as wildlife conservation areas. This is in recognition of the key role played by tourism in foreign revenue generation through tourism (Republic of Kenya, 1999; Okello and Novelli, 2014). Although numerous strategies and financial resources have been used to enhance wildlife conservation, there is rampant population decline of numerous species throughout the country such as the African elephant (*Loxodonta africana*), black rhino (*Diceros bicornis*), gravy zebra (*Equus grevyi*), and large carnivores especially lion (*Panthera leo*) and cheetah (*Acynonix jubatus*), various species of monkeys, hirola antelope among others (Western et al., 2009a).

Numerous studies have examined the causes of decline of wildlife populations in different parts of Kenya - Tanzania borderland (Ottichilo et al., 2000, 2001; Okello and Kiringe, 2004; Western et al., 2009a). Collectively, these studies reveal that a myriad of anthropogenic factors such as; human-wildlife conflicts, illegal wildlife poaching, bush meat activities, increase in human population, alienation or inadequate involvement of locals in conservation initiatives and programs, proliferation of inappropriate land uses like agriculture which compromise wildlife survival and its conservation are responsible for the decline of wildlife. However, the contribution of drought to wildlife decline has not been fully evaluated yet its effects on populations can be devastating just like human related impacts.

In the last century, most parts of Kenya - Tanzania borderland, more so the high potential and heavily human populated have seen tremendous decline and loss of large mammalian wildlife species. However, the borderland Ecosystems are mainly semi-arid region, which until recently was characterized by relatively low and sparse human population is still endowed with diverse free ranging wildlife species. Two major factors have interactively contributed to preservation of wildlife in the ecosystem, elephants included; a semi-arid environment which acts an ecological limitation to land use especially proliferation of rain-fed agriculture, lifestyle, culture and traditions of the Maasai people who are the main inhabitants. The foundation of the Maasai lifestyle is pastoralism which thrives in relatively dry areas and allows livestock and wildlife to co-exist which makes it compatible with wildlife conservation (Berger, 1993; Ntiati, 2002). Further, overtime, various taboos and traditional briefs which abhors eating and indiscriminate killing of wildlife involved among the Maasai, an aspect which has equally contributed to wildlife preservation over the years (Seno and Shaw, 2002; Kangwana, 2011).

Globally, the percentage of land under drought has risen dramatically in the last 25 years, and the incidents of drought, both short and long term, has been rising in Africa (Conway, 2008), including the many ecosystems in the borderland region (Altmann et al., 2002; Thompson et al., 2009). Given the arid to semi-arid nature of the region, droughts can be lead to massive mortality of wildlife especially water dependent species and those which require large amounts of daily food intake. In this regard, the 2007 to 2009 drought in the region provided an opportunity to examine the influence of global climate change on elephants and other key large herbivorous wildlife species, based on data collected during the dry season of 2007, 2010 and 2013.

This research focused on the impact of the 2007 to 2009 drought on population size of key large mammalian wildlife species in the Kenya - Tanzania borderland. It also sought to establish the number and distribution of these key species in the four landspaces on the Kenya / Tanzania borderland. The findings provided insights on appropriate strategies that can be used to mitigate the threat posed to wildlife by droughts and general climate variability that have become common in the ecosystem. Specifically, it addresses the following objectives:i) Determine the current population size of key large mammals in the borderland; ii) Determine the current distribution of key large mammals in the various landscapes of the borderland; iii) Assess the population recovery of key large mammals after the 2007 to 2009 droughts in the borderland area and iv) establish which key large mammal species are of conservation concern and which ones are not following drought – related mortality in the borderland for possible management intervention.

MATERIALS AND METHODS

Study area

The Southern Kenya region comprises of Amboseli National Park, adjoining Maasai group ranches and private lands in the Oloitokitok area along the Kenya-Tanzania border, Namanga, Magadi and Nguruman in the southern part of Kajiado County approximately 8797 Km^2, (Figure 1). On the Tanzania side, it is made up of the Natron and West Kilimanjaro landscapes, and the entire borderland covers an area of >25,000 Km^2. The region has in the recent past experienced a rapid increase in human population particularly in the group ranches and along the slopes of Mt. Kilimanjaro (Ntiati, 2002; Reid et al., 2004; Okello and D'Amour, 2008). Further, it has also experienced widespread land use changes over the past 30 years in response to a variety of economic, cultural, political, institutional, and demographic processes (Reid et al., 2004). Pastoralism is mostly practiced by the predominantly Maasai people in the borderland has continued to decline forcing the community to turn to farming like other ethnic groups (Ntiati, 2002; Okello, 2005; Okello and D'Amour, 2008).

Most of the Amboseli region is classified as ecological zone VI and is characterized by a semi-arid environment, with most of it being suitable for pastoralism and wildlife conservation (Pratt and Gwynne, 1977). It has a bimodal rainfall pattern but the average annual rainfall is quite low ranging between 400 to 1000 mm (Reid et al., 2004). The long rains are normally received at the beginning of the year (between March and May) while the short rains occur at the end of the year (end of October and mid-December) (Western, 1975; Okello and D'Amour, 2008). Thus, rainfall is the key determinant of land use practices in the entire region (Ntiati, 2002; Okello, 2005). Surface water availability is sparse and the hydrology is mostly influenced by Mt. Kilimanjaro. Generally, vegetation of the region is typical of a semi-arid environment, with some of the dominant vegetation communities being; open grasslands, Acacia dominated bushland and the forest belt of Mt.

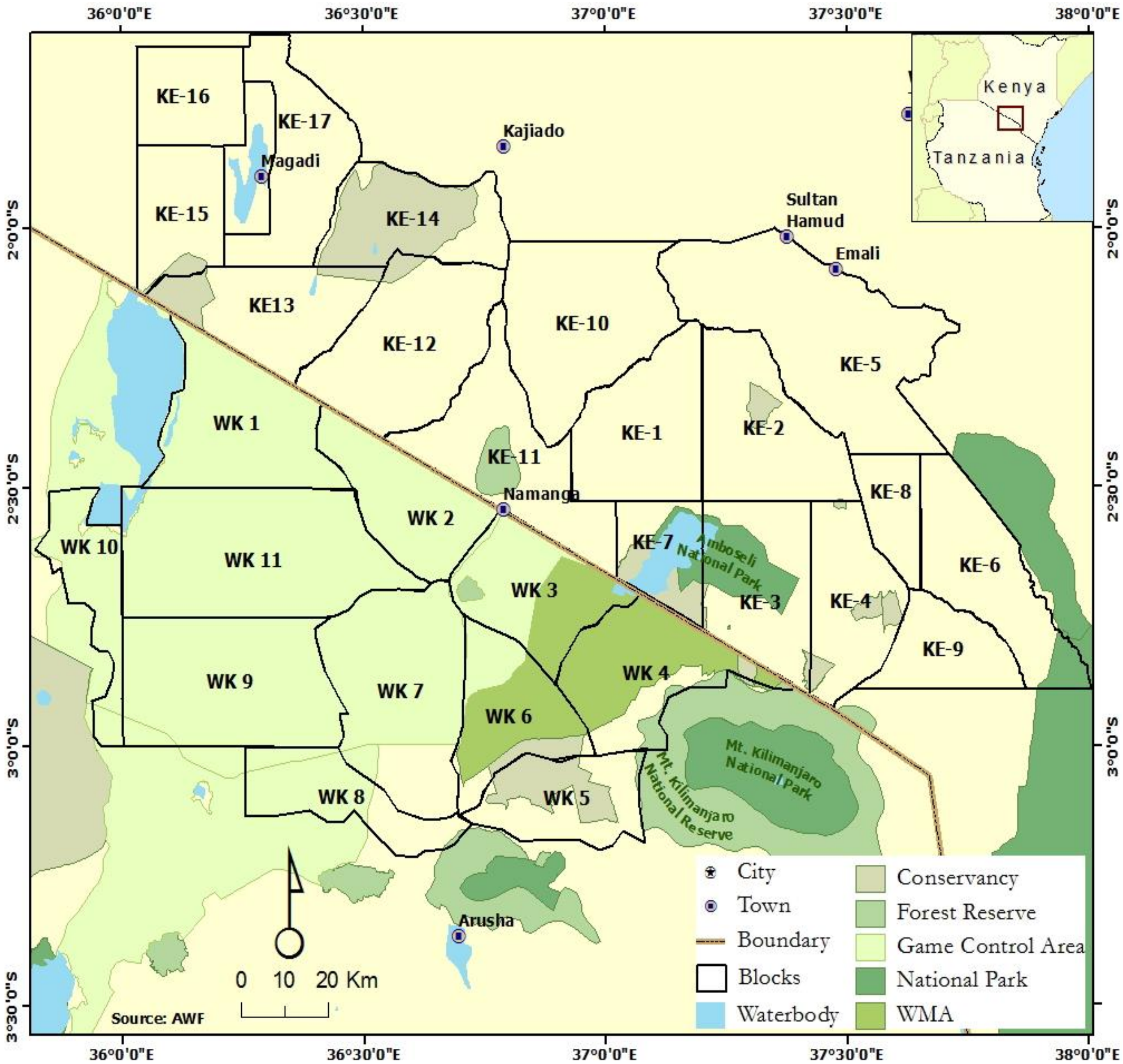

Figure 1. The counting blocks used during aerial counts in the four landscapes (Amboseli, West Kilimanjaro and Magadi – Namanga and Lake Natron) of the the Kenya / Tanzania borderland.

Kilimanjaro, interspersed with patches of swamps-edge grasslands, Acacia woodlands and swamps (Croze and Lindsay, 2011).

The Namanga-Magadi covers an area of > 5, 000 Km^2 most of which comprise of Maasai group ranches (Figure 1). Like other parts of the borderland, it is a semi-arid environment with little rainfall of between 400 - 600 mm, which is bimodal and highly variable and these conditions make it suitable for wildlife conservation and pastoralism (Kioko, 2008). In a few areas, mostly along the Maili-Tisa-Namanga road, the main rivers and Ewaso Nyiro, the locals usually carry out limited irrigated agriculture. There is spatial-temporal variation in vegetation types in response to variation in the landscape and elevation. Due to the semi-arid nature of the region, the soils are poorly developed but are mainly “black clayey” (grumosolic soils) comprising of a variety of “black cotton” soils including the calcareous and non-calcareous variants. Ewaso Nyiro River is the main water sources although there are several seasonal rivers like the Namanga, Ol Kejuado and Esokota.

Lake Natron area lies west of the West Kilimanjaro area, and its northern part is defined by the Tanzania-Kenya border, with a total area of approximately 7,047 Km^2), (Figure 1). It’s largely a semiarid savannah interspersed with open acacia woodlands (Acacia spp. and Commiphora spp.). The southern boundary extends from the southeast corner of Ngorongoro Conservation Area eastward to the northwest corner of Arusha National Park, while the western part is situated along the eastern side of Lake Natron to Ngorongoro Conservation area. Similar to other landscapes of the borderland, rainfall low (<350 mm/year), and is highly variable and largely unpredictable. The vegetation types are very diverse and therefore provide expansive livestock grazing land.

The West Kilimanjaro is found in the Longido District, and its northern sector lies along the Kenya-Tanzania border from Namanga southeastward to Irkaswa covering >3000 Km^2 (Figure 1). Annual rainfall varies depending on the elevation, with the semi-arid lower elevations receiving 341 mm/year and lower elevations on Mt. Kilimanjaro at Mt. Meru and Monduli in the south receiving part 890 mm/year (Moss, 2001). Nevertheless, it is generally

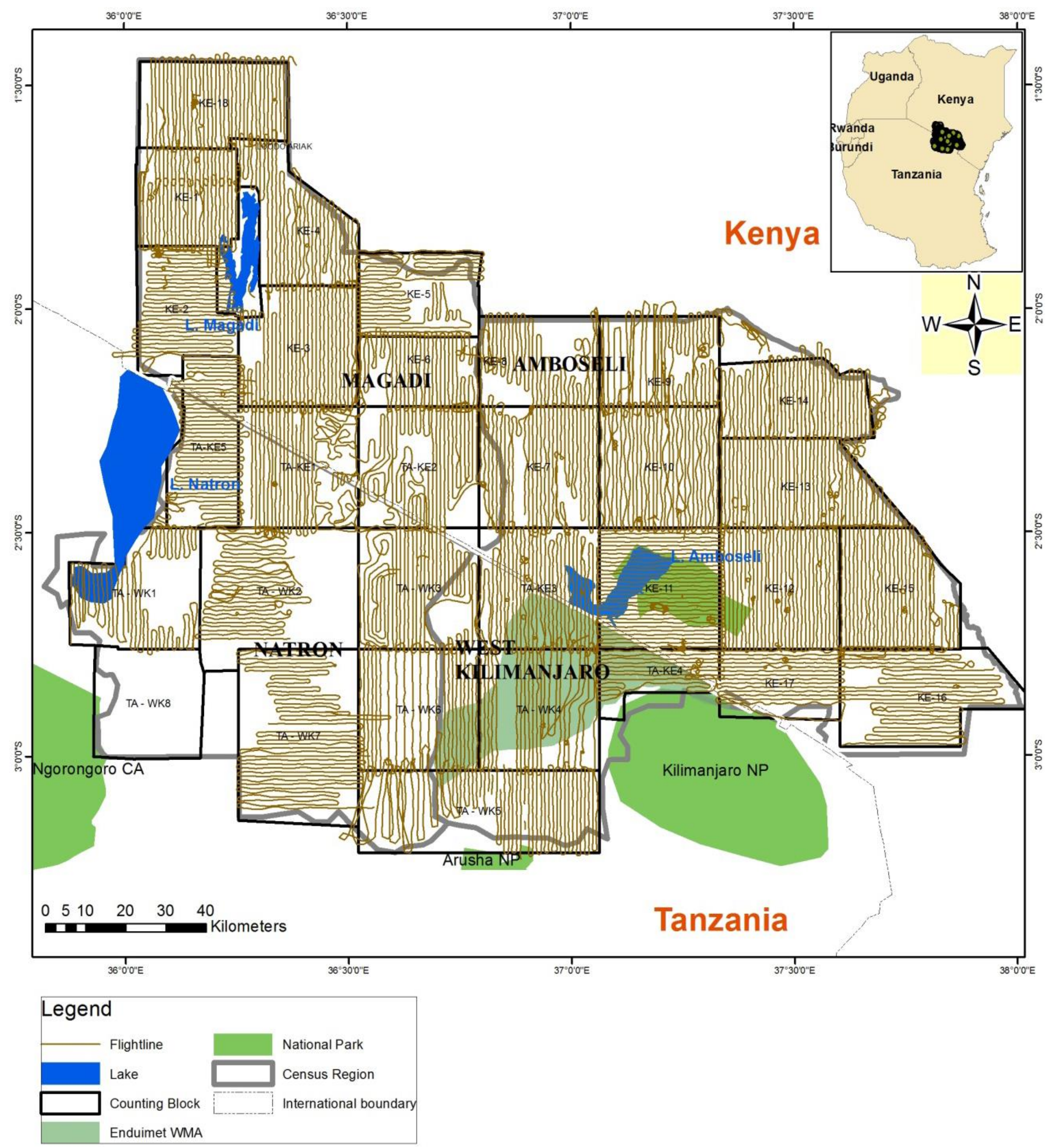

Figure 2. Layout of the census flight paths and flights direction during the large mammal aerial counts in the borderland. Fixed wing aircrafts traversed the study area from south to north at constant speed and height above the sea level.

variable and unpredictable. In terms of vegetation, the region has a complex and heterogeneous vegetation community with extensive swathes of farming and grazing lands. The dominant inhabitants are the Maasai people who have over the years tuned into agro-pastoralists. Numerous wildlife conservation areas are found in the region like Kilimanjaro National Park (755 Km^2), Arusha N. P (137 Km^2, Longido Game Controlled Area (GCA) (1,700 Km^2) and Ngasurai Open Area (544 Km^2).

Methods

For many years since its creation, the Kenya Wildlife Service (KWS) has been undertaking total aerial counts of large herbivores using methods developed by Douglas-Hamilton (1994) and Norton–Griffiths (1978). This approach has generated substantial set of total count data from which trends and dynamics of wildlife populations in the country have been understood. Consequently, wet and dry season total elephant counts were carried out in 2010 and 2013 using similar techniques, and systematically covered the entire area of the defined census zone and recorded every large mammal (and especially elephant herds as they are keystone species in the ecosystem), including their location on the ground using GPS units.

To improve the quality of data collected on the elephant population, both crew and planes were calibrated to aid in estimation of distance for subsequent calculation of observable strip width. Streamers were mounted on either side of the aircraft wings to create two strip categories, the inner and outer (Figure 2). Inner category was defined as the region from the farthest one could see from the belly of the plane to the lower streamer. Likewise the outer category was defined as the region between the lower and the upper streamer (within the streamers). Calibration for observers entailed adjusting the angle of view of the streamers to correspond to 500 M and 250 M on the ground for a set altitude of 300 Ft AGL for the upper and lower streamer respectively. This was done by use of clinometers. The Rear Seat Observers (RSO's) were each calibrated and observer specific and plane specific metrics for each calibration recorded according to an individual's physique. The metrics comprised measurements from various reference points on the air craft such as low and high eye mark on the aircraft window, upper and lower streamer mark on wing strut and plane fuselage. In addition, Front Seat Observers (FSO's) and pilots were also calibrated for the purpose of assisting the RSO's to determine whether or not the counted animals are within the strip width.

For each calibration made, test flights were conducted at the set altitude for streamers (300 Ft AGL) to determine how well the streamers fitted to the desired strip width on the ground. This was achieved by creating a flight line at 500 M and 250 M from a very straight and long (5 KMs) section of a road. When the aircrafts flew on this line, the road was either 500 M or 250 M from the plane and this allowed for evaluation of the streamers. To asses inter observer variability in estimation and enhance species identification, all observers were independently subjected to count a portion of the same block with different species of known numbers in mock flights.

The target landscape was divided into blocks based on visible features from the aircraft like hills, ridges and rivers which helped the pilots to easily navigate during flight. To improve counting efficiency, the blocks were delineated into rectangular and square shapes, which also made it easier for the pilots and the Front seat observers (FSOs) to navigate using GPS units. It also gave them ample time to make comprehensive ground observations, and an attempt was made to ensure the blocks were large enough (about 900 Km^2 each on average), and could be covered within a maximum duration of six hours per day. The enhance reliability of the data collected, the counting crew were trained on how to conduct aerial counts using mock test flights. Thus, different crews flew at different times but maintaining the same flight orientation so as to evaluate any inter observer variation in their ability to identify, detect, estimate and count wildlife species. They were also trained on use of voice recorders, GPS units and cameras, wildlife species identification, counting, estimation of herd sizes, data processing and handling. As noted by Douglas-Hamilton et al., (1994), all this preparation was done in recognition of the fact that the accuracy and reliability of such total aerial counts rely heavily on the experience of the flight crew and the pilot.

Counting of large herbivores was done in each block using a light aircraft which flew along East-West and North-South flight transects of 1-2 Km width depending on the visibility on the ground and nature of the terrain (Figure 2). On average, each count began approximately 7.30 am and ended in the afternoon, and the end time was dependent on the size of each block. The crew comprised on a pilot, front and rear seat observers, and in each block the observers systematically searched for any large herbivores on the ground and recorded; the number of individuals, their spatial location using GPS coordinates, the number, and herds of more than ten individuals were photographed so that the actual number could be verified later (Douglas-Hamilton, 1994). Data capture was also done using tape recorders, and on landing, the ground crew downloaded records captured in digital voice recorders, and the data recorded in the GPS units using DNR-Garmin /MapSource software. Once downloaded, the voice records were processed digitally to remove background noises to enable the data to be clearly heard. A team of transcribers listened to these records transcribed the data onto data sheets, and where there were discrepancies; these were verified, corrected and reconciled. All data were then entered into a spread sheet. Double counts especially on flight lines that were overlapping or very near each other were visually searched and eliminated using GIS software .Flight path and way point data were processed using ArcGIS 10.1 software to produce spatial elephant distribution maps.

In addition to elephant data, the flight observers noted and recorded human activities mainly vegetation clearing, livestock grazing, human settlements and infrastructure development. These were considered to represent key changes in the landscape which threatened its ecological integrity and elephant conservation.

Data from the wet and dry period of 2010 and 2013 were used. Tallies, percentages, means and standard errors for the data were calculated using standard mathematical and statistical methods (Zar, 1999). Population changes were assessed based on how the large mammal density of 2013 varied from 2010 for that particular season.

RESULTS

In the Amboseli landscape (the park and surrounding group ranches), the most abundant herbivores in terms of numbers were the common zebra (averaging 5,165 animals), followed by Grants gazelle (4,593 animals), common wildebeest (3,882 animals), Maasai giraffe (2,063 animals), Common eland (1,349 animals), and the African elephant (1,145 animals) respectively (Table 1). For the Namanga Magadi landscape, the most abundant herbivores in terms of numbers (Table 1) were the common zebra (4,278 animals), followed by Grants gazelle (2,809 animals), common wildebeest (1,979 animals), Maasai giraffe (670 animals), Impala (609 animals), and common eland (347 animals) respectively.

For the West Kilimanjaro landscape, the most abundant herbivores were the common zebra (1,289 animals), followed by Grants gazelle (475 animals), common wildebeest (364 animals), Maasai giraffe (237 animals), Thomson's gazelle (244 animals), and impala (134 animals) respectively (Table 1). For the Lake Natron landscape, the most abundant herbivores were the common zebra (4,181 animals), followed by common wildebeest (3,426 animals), Grant's gazelle (1,333 animals), Maasai giraffe (726 animals), Thomson's gazelle (310 animals), and common eland (210 animals) respectively (Table 1). Similar animals mostly appeared in that order for density (Table 2).

Of the 15 common large mammals in the borderland (Table 1), the five most abundant large wild mammals based on numbers in all landscapes were the common zebra (3828.2 ± 866.2 animals), common wildebeest (2413.1 ± 794.3 animals) , Grants gazelle (2302.7 ± 903.0 animals), the Maasai giraffe (923.6 ± 395.1 animals), and the common eland (494.10 ± 290.32 animals) respectively.

But the five less common large mammals based on their density were the common waterbuck (6.7 ± 2.7 animals), the common warthog (20.1 ± 6.2 animals), the lesser kudu (22.8 ± 7.7 animals), gerenuk (45.2 ± 15.5 animals), and the olive baboon (53.0 ± 17.7 animals). The same five common large mammals and same rare ones was identified based on the average density in the borderland (Table 2) respectively.

However, based on the average percent change in large mammal density in the borderland, the five large

Table 1. Large mammals average numbers in various landscapes in the Kenya / Tanzanina between March 2010 and October 2013.

Species	Amboseli	Namanga / Magadi	West Kilimnjaro	Natron	Borderland average	Position based on numbers
Common zebra, *Equus burchelli*	5164.8	4278.3	1288.8	4581	3828.23 ± 866.23	1
Common wildebeest, *Chonochaetus taurinus*	3882.3	1979.3	364.3	3426.3	2413.05 ± 794.30	2
Grants gazelle, *Gazella granti*	4593.3	2809.3	474.8	1333.3	2302.68 ± 902.98	3
Maasai giraffe, *Giraffe camelopardalis*	2062.5	669.5	236.5	725.8	923.58 ± 395.06	4
Common eland, *Tragelaphus oryx*	1348.5	346.8	70.8	210.3	494.10 ± 290.32	5
Impala, *Aepyceros melampus*	747.3	606.5	134	160	411.95 ± 155.74	6
Thomson's gazelle, *Gazella thomsonii*	621.3	246	244	310.3	355.40 ± 89.96	7
African elephant, *Loxodonta africana*	1144.5	69.3	66.5	27	326.83 ± 272.73	8
Cape buffalo, *Cyncerus caffer*	241.5	58	38.8	14.5	88.20 ± 51.87	9
Fringe eared oryx, *Oryx gazella*	135.8	57.3	37.3	32	65.60 ± 24.03	10
Olive baboon, *Papio anubis*	24.3	104	36	47.5	52.95 ± 17.66	11
Gerenuk, *Litocranius walleri*	90.3	23	26.8	40.8	45.23 ± 15.50	12
Lesser kudu, *Tragelaphus imberbis*	44.5	15.5	22.3	9	22.83 ± 7.72	13
Warthog, *Phacochoerus aethiopicus*	38.5	16.3	11.15	14.5	20.11 ± 6.22	14
Common waterbuck, *Kobus ellipsiprymnus*	12.3	10.3	0.5	3.8	6.73 ± 2.76	15

Table 2. Large mammals' density (animals / km^2) and location performance in the Kenya / Tanzania between March 2010 and October 2013.

Species	Amboseli	Namanga / Magadi	West Kilimnjaro	Natron	Borderland average	Position from least to most concern
Common zebra	0.68	0.71	0.43	0.65	0.62 ± 0.05	1
Common wildebeest	0.43	0.33	0.12	0.49	0.34 ± 0.08	2
Grants gazelle	0.51	0.47	0.16	0.19	0.33 ± 0.09	3
Maasai giraffe	0.23	0.11	0.08	0.1	0.13 ± 0.03	4
Common eland	0.15	0.06	0.02	0.03	0.07 ± 0.03	5
Impala	0.08	0.1	0.04	0.02	0.06 ± 0.02	6
Thomson's gazelle	0.07	0.04	0.08	0.04	0.06 ± 0.01	7
African elephant	0.13	0.01	0.02	0	0.04 ± 0.03	8
Cape buffalo	0.03	0.01	0.01	0	0.01 ± 0.01	9
Fringe – eared oryx	0.02	0.01	0.01	0	0.01 ± 0.00	10
Olive baboon	0	0.02	0.01	0.01	0.01 ± 0.00	11
Gerenuk	0.01	0	0.01	0.01	0.01 ± 0.00	12
Lesser kudu	0	0	0.01	0	0.00 ± 0.00	13
Comon waterbuck	0	0	0	0	0.00 ± 0.00	14
Common warthog	0	0	0	0	0.00 ± 0.00	15

Table 3. Large mammals' percent change in large mammal numbers in various landscapes of the Kenya / Tanzanina between March 2010 and October 2013. Positive is increase while negative indicated a decline in numbers over time.

Species	Amboseli	Namanga / Magadi	West Kilimnjaro	Natron	Borderland average	Position from most to least growth
Impala	92.87	297.14	3498.91	252.37	1035.32 ± 822.36	1
Gerenuk	31.65	1470	1650	126.01	819.42 ± 429.58	2
Common eland	97.22	975.61	1850.53	171.36	773.68 ± 410.36	3
Lesser kudu	543.33	-	912.5	233.33	563.05 ± 170.01	4
Fringe – eared oryx	97.49	947.92	1168.75	-5	552.29 ± 296.36	5
Grants gazelle	55.3	229.74	750.57	268.2	325.95 ± 1248.93	6
Thomson's gazelle	369.28	817.64	39.55	30.18	314.16 ± 185.42	7
African elephant	-5.65	943.27	41.4	275.78	313.70 ± 218.69	8
Common warthog	174.78	500	533.33	15	305.78 ± 126.23	9
Maasai giraffe	44.56	406.46	3.18	57.67	127.97 ± 93.55	10
Common wildebeest	71.66	11.21	315.38	101.4	124.91 ± 66.20	11
Common zebra	10.49	72.51	207.1	86.55	94.16 ± 41.11	12
Common waterbuck	-60.95	458.33	-100	-100	49.35 ± 136.64	13
Olive baboon	-89.47	4.38	225.76	1.85	35.63 ± 80.93	14
Cape buffalo	10.59	-13.71	-100	-100	-50.78 ± 28.85	15

wild mammals whose population was recovering well from the 2007 and 2009 drought were impala (1027.27 ± 827.45%), gerenuk (766.40 ± 406.96%), common eland (696.85 ± 405.85%), lesser kudu (597.87 ± 141.26%), and fringe – eared Oryx (515.67 ± 283.89%) respectively. But the five large mammals that were recovering poorly were the cape buffalo (-54.87 ± 26.80%, still declining), the olive baboon (32.10 ± 67.74%), the common waterbuck (74.05 ± 134.91%), common zebra (87.26 ± 43.28%), and the Maasai giraffe (109.69 ± 77.53%) respectively.

For population growth based on numbers in the Amboseli landscape, large mammals with positive growth were lesser kudu (averaging +543.33%), followed by Thomson's gazelle (+369.28%), and common warthog (174.78%) respectively (Table 3). For the Namanga Magadi, the animals with positive growth were the common eland (averaging +975.61%), followed by fringe – eared Oryx (+947.92%), African elephant (943.27%), Thomson's gazelle (817.64%), common warthog (+500.00%), Maasai giraffe (406.46%), impala (297.14%), and Grant's gazelle (229.74%) respectively. For the West Kilimanjaro, the large mammals with positive growth were impala (+3498.91%), followed by fringe – eared Oryx (+1168.75%), common eland (1850.53%), gerenuk (1650.00%), lesser kudu (912.5%), Grant's gazelle (750.57%), common warthog (+533.33%), common wildebeest (315.38%), and common zebra (207.10%) respectively (Table 3). And for Lake Natron landscape, the animals that showed higher positive growth were the African elephant (averaging +275.78%), followed by Grant's gazelle (+268.2%), impala (252.37%), lesser kudu (233.33%), common eland (+171.36%), and common wildebeest (101.4%) respectively (Table 1).

Overall, based on all the population parameters (numbers, density and population change (increase or decline), the large mammal species that declined more were common waterbuck, olive baboon, cape buffalo, common warthog, lesser kudu and African elephant respectively. Those of relatively less concern were impala, common eland, Grant's gazelle, common wildebeest, common zebra and Maasai giraffe respectively.

In terms of each landscape status within the borderland based on the large mammal parameters, Amboseli landscape had a higher and positive indicators followed by Magadi / Namanga area, West Kilimanjaro and lastly Lake Natron area (Table 4). Amboseli landscape led in numbers and density, but had the lowest values on population growth. Namanga / Magadi landscape was the second, but with the highest herbivore growth in numbers and density after West Kilimanjaro (Table 4). West Kilimanjaro had the lowest values in terms of herbivore numbers and density in the borderland. But it led in terms of large mammal growth rate. Lake Natron area showed low herbivore numbers and density and also low population growth rate (Table 4).

DISCUSSION

Wildlife large mammals are declining sharply both in protected areas (irrespective of the size) and outside

Table 4. Large mammal population parameters in various landscapes of the Kenya / Tanzanian borderland between March 2010 and October 2013.

Parameter	Aspect	Location within the borderland				Borderland average
		Amboseli	Magadi / Namanga	West Kilimanjaro	Lake Natron	
Large mammals (animals)	Average values	1343.45 ±444.15	752.63 ±317.90	203.50 ± 83.09	729.07 ±348.65	757.16 ± 288.92
	Rank	1	2	4	3	
Large mammal number (%) of landscape	Average values	51.77 ± 4.41	21.16 ± 3.12	9.66 ± 1.50	17.41 ±2.22	Not necessary
	Rank	1	2	4	3	
Density (animals / km^2)	Average values	0.16 ± 0.05	0.12 ± 0.05	0.07 ± 0.03	0.10 ± 0.10	0.11 ± 0.04
	Rank	1	2	4	3	
Change (%) in large mammal density	Average values	87.91 ± 38.92	438.43 ± 104.17	792.80 ± 248.57	103.18 ± 34.96	346.26 ± 78.02
	Rank	4	2	1	3	
Change (%) in large mammal numbers	Average values	96.21 ± 40.86	508.61 ± 114.35	733.13 ± 246.31	94.31 ± 31.35	358.97 ± 81.15
	Rank	3	2	1	4	
Overall landscape rank based on all parameters		1	2	3	4	

dispersal areas in Kenya (Western et al., 2009a). This work specific at the Kenya – Tanzania borders shows post drought (of 2007 and 2009) common large herbivore numbers and population change over a three year wet and dry season counts done for cross – border monitoring purposes. The causes for large wild herbivore declines (Western et al., 2009a) are natural such as droughts (Western, 2000), diseases, environmental and demographic stochasticity; as well as human – induced causes such as encroachment, poaching and persecution, loss of habitat and human encroachment (Okello and Kiringe, 2004); and management and policy failures such as management lapses as well as lack of stakeholder support, and participation, especially some local communities (KWS, 1994).

Even though the droughts of 2007 and 2009 may have reduced the wildlife populations, the subsequent rains increased forage and water availability in the borderland. This increased resources and reduced competition for them spurred an increase in mammal numbers (likely through birth. Those animals which have recovered well and the population continues to increase in the borderland include zebra, wildebeest, Grant's gazelle, Maasai giraffe, the common eland, impala, Thomson's gazelle and the African elephant. Both their numbers and population increase in the landscape is on the rise.

However, there as species in the borderland that are either not recovering well or their population numbers are still low. These species include Cape buffalo, waterbuck, olive baboons, lesser kudu, gerenuk, fringe – eared Oryx and common warthog. Even though lesser kudu, common warthog, fringe – eared Oryx and gerenuk seem to be recovering well though population growth, their numbers are still low. Populations whose numbers are low are prone to environmental and demographic stochasticity faster and can easily be wiped off by these events and become locally extinct (Mwangi and Western, 1998; Ogutu and Owen – Smith, 2003). But those which are still abundant but are declining (low or negative growth) are also in danger of downward population trend with time.

Care need to be taken for species with specific habitat needs (such as the gerenuk and lesser kudu) and those who are highly dependent on localized resources (such as waterbuck and cape buffalo that are water dependent) as these are more exposed to rapid population declines if poor habitats and environmental stochasticity persists (Western and Gichohi, 1993;Western and Ssemakula, 1991). It is therefore important the continuous monitoring using same methods and standards as used in this aerial counts for both wet and dry season continue over the years in the borderland to monitor these species, as well as those not reported here (such as carnivores) so that management and conservation measures are taken to help them build back their population numbers in all the areas of the borderland.

Elephants use a large area and play a critical keystone function in the ecosystem. Even though elephant numbers in Amboseli stood at an average number of 1,145 (about 88% of the borderland) compared to Magadi / Namanga (5%), West

Kilimanjaro (5%) and Lake Natron area (2%) of the total estimated 1,308 in the borderland, the later locations can support more elephants. Further, the Amboseli National Park, the surrounding Maasai group ranches, and the now emerging private and communal group ranches have the potential to support more elephants than this. It is for this reason and the fact the elephant is an ecological keystone species, a conservation flagship species, and an IUCN endangered species persecuted internationally for its ivory that the African elephant is still regarded as a species of concern (Western and Lindsay, 1994).

If the dispersal areas range can be made safer with expanded space in community and private ranches providing additional elephant core use areas with enough forage and water and little competition and degradation from livestock and people, elephant numbers will continue to recover and increase in the ecosystem that reported in this study. Indeed it's noteworthy that already the African elephant had a negative growth rate in Amboseli and very little growth in West Kilimanjaro may be because of habitat changes (Western, 2006) and land use changes (Okello, 2005). If poaching and habitat degradation can be contained especially in the Lake Natron and West Kilimanjaro areas, and human encroachment and human – elephant conflicts contained in the Amboseli and Magadi / Namanga areas, elephant numbers will increase to use the entire borderland (Kikoti, 2009).

Amboseli, Magadi / Namanga, West Kilimanjaro, and Lake Natron areas had lower large mammal parameters (large mammal numbers, density, and population growth). Even though most of the parameters showed Amboseli as the most important area for large mammal conservation in the borderland, its importance may lie in supporting the largest number and density of large mammals, and also in being a source (for mainly immigrating species) especially during the wet season. Amboseli has permanent water sources with continuous green biomass growth and this is what attracts most large mammals to the area and especially in the dry season. With less incidences of commercial poaching, the role in supporting higher numbers and being a source for other areas in the borderland cannot be over - emphasized. But growing cases of bush meat trade, increasing human encroachment on wildlife dispersal areas, land use changes, agriculture expansion and increased commercial and industry investments in the area threaten Amboseli as a wildlife hub. If the Amboseli Ecosystem is not made safer and threats to wildlife and conservation urgently tackled, its role will diminish as already wildlife growth generally has stagnated in the ecosystem even if it is likely that resources (space, forage and water) and ecological niches may already be saturated by available species and numbers.

Namanga / Magadi landscape seemed to be the most promising area in the landscape supporting current population numbers and having real potential for herbivore population growth as well. However, this can only happen if habitat destruction and poaching are contained, as well as local communities inducted in conservation process by being encouraged to conserve, set aside wildlife conservancies for ecotourism and collaboration with conservation agencies and organizations in enhancing conservation in this area. This is already happening, but needs to be structured and planned better, and supported with both financial and technical expertise. The West Kilimanjaro area, though having low numbers, has a great potential for wildlife large mammal population increase because the results indicated that it had the leading species growth rate (immigration and birth rate may be higher than other locations). But for this potential to be achieved, urgent measures are needed to stem out mainly poaching and habitat destruction in this general area before meaningful wildlife population numbers can build up. The Lake Natron area seemed to stand out as a hot spot of likely wildlife local extinctions and unsafe range for wildlife presence. This is because this area had the lowest numbers as well as rate of population growth. This means the birthrate are low and likely the immigration of individuals from other populations into the area from other areas is poor. This may be due to high rate of poaching, hunting, habitat degradation (Kiringe and Okello, 2005) and animal harassment in the area. Urgent measures are needed to stem out mainly poaching and habitat destruction in this general area before meaningful wildlife population numbers can build up.

This research finding demonstrates two important issues for the conservation of the borderland. First, the collaboration of governments (Kenya and Tanzanian through their lead wildlife agencies) and conservation organizations in doing joint wildlife census, monitoring, and security operations on the borderland to enhance wildlife conservation is critical. This partnership can be maintained and enhanced through relevant intergovernmental legal protocols under the East African community and for the benefit of communities and wildlife living in the borderland area. Second, it is very important to establish status and trends of wildlife populations through consistent, standard and improved methodology. This research was done the same way in wet and dry season and covered the same area. Improvement in data collection, collation and aerial techniques continued to improve the reliability of the data and provision of very good baseline data that can be a basis for future analysis and comparisons. However, the data on small animals (especially baboons, dik diks, warthogs and most carnivores) cannot be very reliable because of small size from the air or preferred habitats (such as baboons that live in riverine woodlands) and this technique may bias proper estimates of those species. A better alternative methodology for these species (including carnivores) needs to be evolved and done separately.

Conflict of interests

The authors did not declare any conflict of interest.

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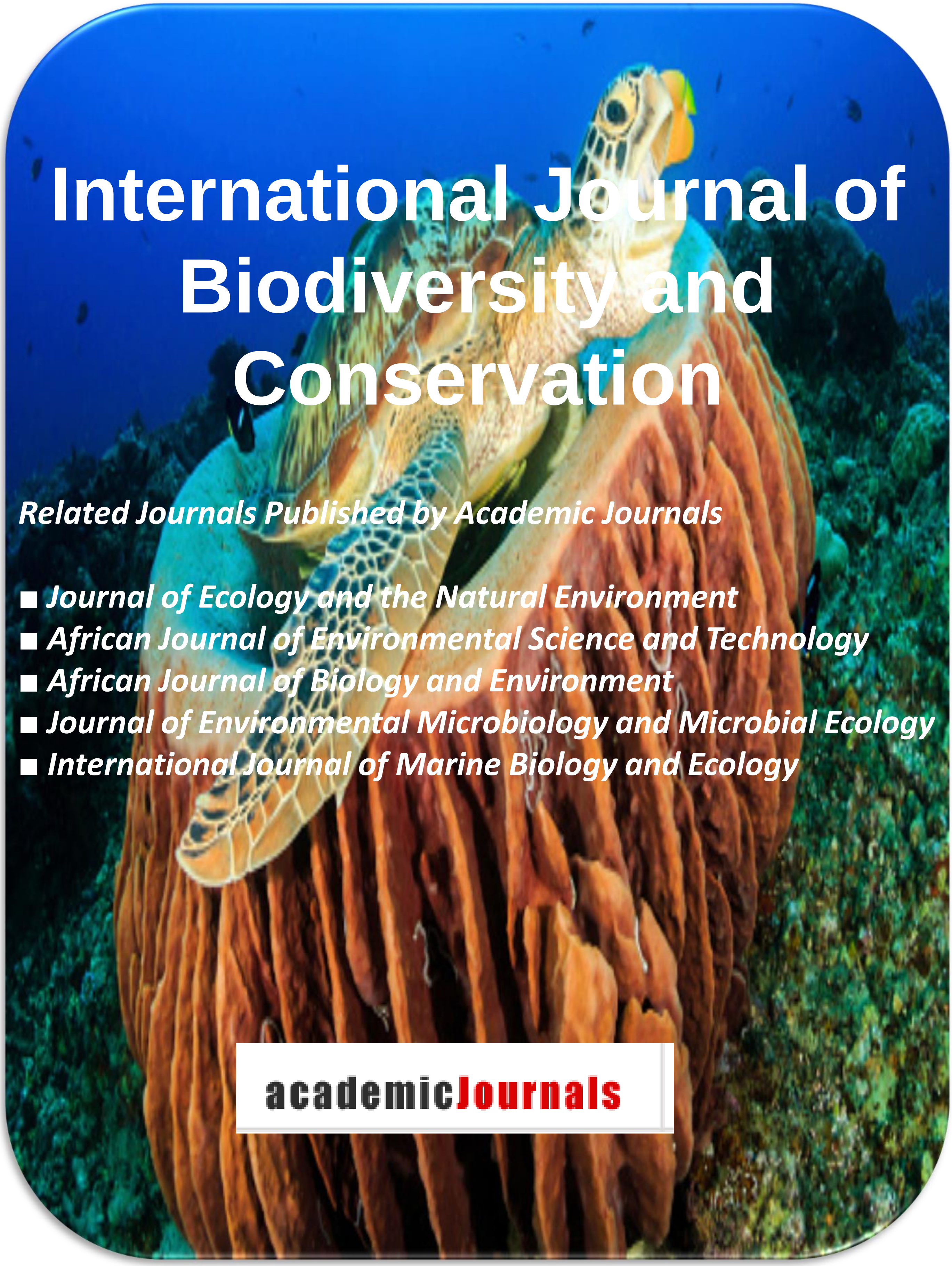

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