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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

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

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Review

Biodiversity in Khajjiar Lake of Himachal Pradesh, India: Threats and conservation

Vikram Singh* and H. S. Banyal

Department of Biosciences, Himachal Pradesh University, Shimla-171 005 (HP), India.

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Faunal resources of Kalatop-Khajjiar sanctuary, which is one of the oldest preserved forests of the state are under severe anthropogenic pressure and need urgent attention of the field biologists as it is one of the most favoured tourist destinations in Himachal Pradesh. Biodiversity of Khajjiar area of Himachal Pradesh has 223 species of different faunal groups (invertebrates and 100 vertebrates), comprised of 93 genera, 79 families and 32 orders. Out of these, 3 species of butterflies are placed under Wildlife Protection Act (1972) and 13 mammals have been placed under Indian Wildlife Protection Act 1972. While nine species of mammals has been listed as threatened in Convention in Trade of Endangered Species (CITES). Two critically endangered birds, Indian White-backed Vulture and Red-headed Vulture are also recorded. Ecological equilibrium of the study area is no more in a balanced state due to increased development and human intervention.

Key words: Khajjiar Lake, ecological imbalance, faunal diversity, pollution.

INTRODUCTION

Biodiversity, encompasses variety and variability of all life on earth. It has been generally defined as the 'full variety of life on Earth'. More specifically, biodiversity is the study of the processes that create and maintain variations. It is concerned with the variety of individuals within populations, the diversity of species within communities, and the range of ecological roles within ecosystems. Biological diversity or biodiversity refers to the diversity of life. Biodiversity is the result of evolutionary plasticity of living organisms, and increased geometrically through perhaps 3.5 billion years, proliferating by trial and error, controlled by natural selection, filling almost every one of the habitable ecological niches created in a likewise evolving world environment. The variability among living organisms from all sources includes terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

The word biodiversity which is the abbreviated from the word biological diversity appears to have come into prominence around 1980, when Norse and McManus (1980) first defined it. Its abbreviation into 'biodiversity' was apparently made by Walter (1985) during the first planning meeting of the 'National Forum on Biodiversity' held at Washington DC in September 1986 (UNEP, 1995). The book entitled biodiversity (Wilson and Peters, 1988) introduced the notion of biodiversity and popularized this word among the scientific community as well as the

*Corresponding author. E-mail: proliterate@yahoo.com. Tel: +91 9418484418.

public. Since then, not only the number of publications on biodi-versity, but also people interested in the subject for one reason or the other has steadily increased. United Na-tions General Assembly has declared 2011-2020 as "Uni--ted Nations Decade of Biodiversity" and 22nd May of every year is celebrated as International Day for Biodiversity.

India is situated at the tri-junction of the Afro-tropical, the Indo-Malayan and the Paleo-Arctic realms, which dis-play significant biodiversity. Being one of the 17 identified mega diverse countries; it is home to 8.58% of mamma-lians, 13.66% of avians, 7.91% of reptilians, 4.66% of amphibians, 11.72% of fish, and 11.80% of plant species documented so far. From the biodiversity standpoint, India has some 59,353 insect species, 2,546 fish species, 240 amphibian species, 460 reptile species, 1,232 bird species and 397 mammal species, of which 18.4% are endemic and 10.8% are threatened (Varughese et al., 2009). Among species found in India, only 12.6% of mammals and 4.5% of birds are endemic, as against 45.8% of reptiles and 55.8% of amphibians. India has 172 (2.9%) of the IUCN designated threatened species. It has been estimated that at least 10% of the country's recorded wild flora, and possibly the same percentage of its wild fauna, are on the threatened list, many of them are on the verge of extinction (Varughese et al., 2009).

Traditional and substantial dependence on biodiversity and faunal resources for fodder, fuel wood, timber and minor forest produce has been an accepted way of life for the rural population that accounts for nearly 74% of India's population. With radical demographic changes, the land to man ratio and forest to man ratio has rapidly declined. The lifestyles and the biomass resource needs having remained unchanged, the remnant forests have come under relentless pressure of encroachment for cultivation, and unsustainable resource extraction, ren-dering the very resource base unproductive and depleted in its biodiversity. Today, this diversity of life is threatened by human activities, although the exact rate of species loss is difficult to ascertain. These activities are unabated human population growth, overexploitation of resources, pollution and global climatic change. Disappearance of species is not an aberrant process in the course of time. Biologists estimated that natural rate of extinction is about one per one million species in a year which is also referred as 'background' rate of extinction. In the deep past, species were also wiped out in large scales due to extrinsic factors that were beyond normal environment regime. Species evolution and extinction are very much part of evolutionary history of biotic world. But the con-cern on the alarming rate at which species are going to extinction today due to reckless alteration and degrada-tion of environment quality and putting the very future at risk. The current rate of species extinction is about 1000 times faster, while the evolution of new species is limited by evolutionary constrains (Saikia et al., 2010).

As per the IUCN Red List, 2008, India has 413 globally threatened faunal species, which is approximately 4.9% of the world's total number of threatened faunal species. These include 53 species of mammal, 69 birds, 23 rep-tiles and 3 amphibians (Varughese et al., 2009). India has globally important populations of some Asia's rarest animals, such as Asiatic Lion, the Bengal Tiger, and the Indian White-Rumped Vulture.

If the present rate of decline continues, half of the world's species will get extinct in 21st century. It has been predicted that 20% of the world's species would get extinct within next 30 years and at least 50% in the de-cades that follow. Presently, biodiversity on the earth is being impoverished at an alarming rate, just at the time when man needs it most for sustaining its own life. It is now well recognised that the well-being of human beings and biodiversity are more interdependent than ever before. Virtually all governments, organisations and com-munities have responded to this situation in several ways.

The faunal and floral diversity in Himachal Pradesh is also very rich and diversified, primarily due to varied climatic conditions ranging from tropical in the foothills to arctic environment in the Trans-Himalayan region. Rich diversity of animals in Himachal Pradesh is reflected by the presence of 2,542 faunal species belonging to diffe-rent groups as compared to 89,500 animal species of the country (Mehta, 2005). Himachal Pradesh has a small geographical area of 55,673000000 square meters which is only 1.7% of India but it harbours more than 7% of the total fauna of the country. Invertebrates constitute 88.4% and vertebrates 11.6% of the fauna in Himachal Pradesh. Insects and other arthropods form a predominant group (4,641 species) among invertebrates, whereas vertebra-tes are dominated by birds comprising about 447 (610, revised) species (Mehta, 2005).

Keeping in view, comprehensive studies were con-ducted from July, 2008 to June, 2012 on enumeration of different faunal groups in Khajjiar Lake and surrounding areas. Based on the above, field based conservation measures have also been elucidated for betterment of the biodiversity of Khajjiar Lake area. The lower animal groups were collected, preserved, identified and studied strictly following the wildlife conservation provisions. However, direct observations were made on large ani-mals in their natural habitats and no individual was caught or hurt during the observations. So, different met-hods like hand picking, sweeping, aerial netting, aspirator and light trap have been employed for study of lower (invertebrate) animal groups. Methods employed for vertebrate fauna included visual sighting, trapping with net and photography. Quantification of indirect evidences in mammals was done with standardized methods such as pellet groups, scats, pug marks and hoof marks.

STUDY AREA AND METHODOLOGY

Khajjiar Lake "The Mini Switzerland of Himachal

A

B

Plate 1. A: Khajjiar Lake area in winter; B: Khajjiar Lake area in summer.

Pradesh" is present in the western part of Chamba district of Himachal Pradesh (Plate 1). Khajjiar Lake has a clump of reeds and grasses exaggeratedly called an island in it. Fed by slim streams, this small lake rests in the centre of large glade of Khajjiar. This glade is greenish in its turf and contains in its centre a small lake having approximate area of 4180 square metres. The glade is surrounded from all sides by a thick forest of deodar (*Cedrus deodara*), fir (*Abies pindrow*) and spruce (*Picea smithiana*) (Plate 1).

Khajjiar Lake lies at 32°26´ north and 76°32´east at an altitude of about 6300 ft (1920 m) above sea level between Chamba and Dalhousie. The average depth of this lake is stated to be thirteen feet as per district gazetteer. This lake remains full of water in all seasons. It requires no rain water for survival. There is a 'golden' domed temple at the edge of this meadow, dedicated to the deity 'Khajjinag', from whom the area derives its name. Khajjiar Lake is situated in the centre of Khajjiar-Kalatop wildlife sanctuary. This small sanctuary lies in the catchments of the Ravi River, located in western part of Chamba district. It is one of the oldest preserved forests of the state (noti-

fied on 01.07.1949) (Singh and Banyal, 2012). Total area of sanctuary is 2,026.89 hectares (20.69 sq. km.) Geographically, it is situated at the Northwest termination of Dhauladhar range in the middle Himalayas. Its mean annual rainfall is 800 mm. Temperature varies from -10 to 35°C.The climate of Khajjiar is alpine. Summers (April-June) are mild and winters (November-February) are cold and bitter (Plate 1). It experiences south-western monsoon rains in July-September.

Despite a few studies on biodiversity of birds in Chamba district of Himachal Pradesh, this area has not been sufficiently explored. Similarly, only some of the faunal elements like birds and beetles have been enlisted from Kalatop-Khajjiar sanctuary and no information is available on other faunal groups of this sanctuary. Moreover, faunal resources of Kalatop-Khajjiar sanctuary which is one of the oldest preserved forests of the state (notified on 01.07.1949) are under severe anthropogenic pressure, need urgent attention of the field biologists as it is one of the most favoured tourist destinations in Himachal Pradesh.

Faunal diversity of Khajjiar Lake area

Biodiversity of Khajjiar area of Himachal Pradesh is represented by 223 species of different faunal groups (123 invertebrates and 100 vertebrates), comprised of 193 genera, 79 families and 32 orders. Analyses of data shows that class Aves dominated the fauna of Khajjiar with 77 species, followed by Lepidoptera (49 species), Orthoptera (29), Mammalia (16), Coleoptera (15), Odonata (10), Hymenoptera (7), Hemiptera and Diptera (5 each), Reptilia (4) and Amphibia (2 species). It is further analyzed that Mollusca, Oligochaeta, Homoptera and Pisces are least represented groups of fauna with a single species each in Khajjiar area.

These 123 species of invertebrates belongs to 110 genera, spread over 30 families and 10 orders from Khajjiar area. Of these, Lepidoptera (49 species) is the most dominant invertebrate order in the present study area, followed by Orthoptera (29 species), Coleoptera (15 species), Odonata (10 species), Hymenoptera (7 species), Hemiptera and Diptera (5 species each), and Mollusca, Oligochaeta and Homoptera (1 species each). Comparison of number of species of invertebrates recorded presently and known from Himachal Pradesh (Mehta, 2005) reveals the presence of 6.6% of the invertebrate fauna of the state in Khajjiar area. Similarly, invertebrates constitute more than 55% of the total fauna of Khajjiar area. A total of 121 species of insects belonging to 108 genera comprised of 28 families and 8 orders also present in Khajjiar area. It forms about 55% of the total fauna of the study area and 98% of the invertebrates.

Ten species belonging to 8 genera comprising of 5 families of odonates are present in Khajjiar lake area. Khajjiar area supports a total of 29 species of Orthoptera belonging to 28 genera, under 5 families. Orthopterans of Khajjiar area represent more than 17% of the state fauna and form more than 23% of the total invertebrate fauna of the present study area. Only 5 species of hemipterans belong to 4 genera and 2 families and single species of Homoptera (*Platylomia saturate* Walker, 1858) belonging to family Cicadiae is present in Khajjiar area. 15 species of beetles belonging to 15 genera and 7 families are present in Khajjiar and surrounding area of Chamba district. It corresponds to 12% of the invertebrate and 7% of the total fauna of Khajjiar area. A total of 49 species of butterflies belonging to 41 genera and 10 families are recorded from the study area Khajjiar area of Himachal Pradesh. It constitutes about 39% of the invertebrate and about 22% of the vertebrate fauna of the Khajjiar area. Categorization of the species further revealed that of these 49 species, 5 were very common, 32 common, 5 uncommon and 7 were rare. Moreover, 3 species were placed under Wildlife Protection Act (1972). These included *Lethe scanda* and *Lampides boeticus* placed under scheduled II and *Castalius rosimon* under scheduled IV of the Act.

Presently, 5 species of dipterans belonging to 5 genera, 3 families are in Khajjiar area of Chamba. It constitutes about 4% of the invertebrate and 1.7% of the total fauna of Khajjiar area. A total of 7 species of hymenoptera belonging to 6 genera and 5 families have been recorded from Khajjiar area of Himachal Pradesh. It forms about 6% of the invertebrate and 3% of the total fauna.

A total of 100 species of vertebrates belonging to 83 genera, spread over 49 families and 22 orders, representing about 45% of the total fauna have been recorded from Khajjiar area. The present investigations revealed the presence of 77 species of birds belonging to 62 genera, 12 orders and 31 families. Birds represent 77% of the vertebrate and 34.5% of the total fauna of the Khajjiar. Khajjiar Lake and surrounding area supported 20 species of birds which are local and rest 57 are seasonal-local and long range migrants. The birds placed under resident category included critically endangered Indian White-backed Vulture and Red-headed Vulture. Of the 57 species, 35 are seasonal-local migrants, 4 are winter visitors and 10 are summer visitors. Moreover, Khajjiar Lake supports 8 of such species which shows winter and summer influx. Of these, 6 shows summer influx, whereas, winter influx is shown by 2 species only. Analyses of data on relative abundance shows that 25 species of birds are very common, 30 are common, 21 are uncommon and 1 is rarely seen in the area under investigation. Further analysis of residential status and relative abundance reveals that of the 20 resident species, 10 are very common, 8 are common and 2 are uncommon. Of the 57 seasonal-local migrants, 15 species are very common, 24 are common, and 17 are uncommon and only 1 species is rare. Categorization of 4 winter visitors reveals that 2 are uncommon, 1 each is common and rare. Moreover,

analysis of data on relative abundance of summer migrants shows that of the 10 species, 1 species is very common, 5 are common and 4 are uncommon. Grouping of the species among winter and summer influx reveals that of the 2 species which shows winter influx, 1 each is common and uncommon , whereas, out of 6 species that shows summer influx 1 is very common and 5 are common in the Khajjiar lake area.

Moreover, 16 species of mammals belonging to 14 genera, 12 families and 6 orders are also present in the Khajjiar wildlife sanctuary. Nine species has been listed as threatened in Convention in Trade of Endangered Species (CITES) under different schedules. Five species namely *Semnopithecus ajax*, *Ursus thibetanus, Panthera pardus, Naemorhedus sumatraensis* and *Naemorhedus goral* have been placed in schedule I, *Macaca mulatta* in schedule II and *Vulpes vulpes, Martes flavigula* and *Mustela sibrica* under schedule III. Out of a total of sixteen species thirteen have been placed under Indian Wildlife Protection Act 1972. Two species *P. pardus* and *N. sumatraensis* have been kept under schedule I. Same species have been considered as vulnerable species according to National Red Data.

Threats and conservation of biodiversity

Biodiversity has three important categories of values viz., productive use value, consumptive use value and indirect values. Productive use value is a value assigned to products that are commercially harvested for exchange in formal markets and is, therefore, the only value of biological resources that is reflected in national income accounts. On the other hand, consumptive use value is the value placed on natural products that are consumed directly. The value of such goods can be considerable. Indirect values are related primarily to the functioning of ecosystems, do not normally appear in national accounting systems, but they may far outweigh consumptive and non-consumptive values (Alfred et al., 1998). The biodiversity in Khajjiar lake area, like other parts of Himachal Pradesh is very rich and diversified, but, in recent years, area of Khajjiar in particular and the state in general have come under a strong threshold of development. Natural ecosystems/habitats have been over-exploited and even destroyed by the rapidly increasing human population and tourist inflow. A number of endemic and restricted range species found in the area/region are facing threat of their existence (Vedwan and Rhodes, 2001).

There already exist many programmes/acts which if strictly followed, can play an important role in the preservation of bio-diversity of not only urbanized areas but in rural and forested areas too. Wildlife Protection Act (1972), National Wildlife Action Plan (1983), National Biodiversity Strategy and Action Plan (NBSAP) etc., all envisage objectives which aim at all active protection and development of forest resources, conserving nation's biodiversity and strengthening efforts to protect wild species and varieties. Convention on Biological Diversity (1992) emphasizes various objectives all of which have one fact in common, that is, protection of nature and natural resources. Moreover, India has a well developed Protected Area Network (PA's) comprising 89 National Parks (covering an area of 37,530.76 km^2 or 1.14% of the country's geographical area) and 489 Wildlife Sanctuaries (1,17,042.04 km^2 or 3.56% of the country's geographical area). Khajjiar Lake is also one of the richest and oldest preserved wildlife sanctuaries of the country. Put together, the 578 PA's cover about 4.70% of the country's geographical area (Rodgers et al., 2002).

Ecological equilibrium of the study area is no more in a balanced stage due to developments and human interventions. With the passage of time natural food plants of Monkeys and Langurs have decreased in the forest and these animals have came out of their natural habitat and forced to live near or around human population. Similar observations have been made in some studies conducted in different parts of country in recent past. Southwick and Siddiqi (1994) reported that in the northern parts of our country, normally 86% of rhesus monkey population depends entirely upon human settlements for their food, however; only 14.4% of the rhesus macaques live in isolation from humans and do not rely on them at all for food. It is observed that leopard prefers easily available food in the form of domestic animals and stray cattle, therefore, natural check on monkey is not there. Feeding habits of monkeys and langurs in present study area have also changed. Now they have become more dependent on human left outs like baked or cooked food available near the human population, offered by tourists and leftover of the hotels. In the recent past, it has been recorded that Rhesus and Langurs usually raid the crops of the natives and cause huge economic losses to them. A new kind of conflict has developed between the ecology of these animals and local farmers. Various incidences of violence of monkeys against tourist are also commonly recorded in Khajjiar area (Singh and Banyal, 2012).

Similarly, with increasing intervention of man into forest incidences of encounters between man and bear has also increased in Kalatop-Khajjiar area. Most of the places are remote and there is no access to the vehicle so local people have been using the forest path and sometime it gives rise to bear-human interface. With decreasing food resources bears are forced to raid maize and other crops of farmers. It is observed that the amount of the destruction of the crop was much higher than they actually eat. Earlier when the food resources were available in the forest this kind of raids of crops were rarely observed as informed by people. Although monkeys, langurs and bears are in conflict with humans but no incidences of their killing was recorded from the area.

Another important concern of ecology which is noticed is of domesticated cattle and cows (Plate 2). These are in

Plate 2. Different tourist games and grazing of domestic animals in Khajjiar Lake.

huge numbers and can be seen grazing in and around the Khajjiar lake. Further, population of these stray animals is increasing day by day. This leads to increased addition of faecal matter in the lake which is leading to eutrophication of lake (Plate 3). Many times these stray animals enter forest for grazing and destroy undergrowth of forest. With ever increasing number of tourists reaching Khajjiar every year the number of hotels in the area is increasing. This is good for general socio economic development of the area but has adverse impacts on ecological health. Many tourists visit deep in the forests and enjoy tracking in the hills. Hotels and tourists produce a large quantity of non degradable garbage which accumulates in and around the lake and also deep into the forest. This non degradable garbage also interferes with the rejuvenation of forest organic mass which impacts floral and faunal diversity.

Khajjiar area of Himachal Pradesh has seen a tremendous increase in population in the last decade, due to which natural habitats are in great pressure. The future of the unique Himalayan Wildlife found in the present study area of Khajjiar, therefore, requires immediate involvement of scientific inputs, political will and collective public participation in saving biodiversity from imminent danger of appalling extinction. Keeping in view the imminent dangers of extinction to bio-diversity following measures can be adopted.

There is huge number of stray animals which can be seen grazing around the lake. This leads to increased addition of faecal matter in the lake which is leading to eutrophication of lake. So entry of domesticated animals should be restricted to the meadow. For this a barbet wire fencing the lake and meadow can serve the purpose. Additionally, immediately around the meadow number of horses can be seen which are used for horse ring by the tourist. These horses add to the economy of people but have adverse impact on health of lake through their dung. So proper management of horse dung is immediately needed. As discussed earlier increasing hotel industry is adding huge quantities of non-biodegradable as well biodegradable wastes like plastics and bottles, which is disturbing natural growth of vegetation in the forest as well as in meadow. Proper management of this waste is required.

Khajjiar is one of the favorite tourist destinations for tourists and huge population of tourists is visiting the meadow every year so there should be some check on the entry of tourists to this place. Various types of tourist sports take place in the Khajjiar meadow. These disturb the normal growth of meadow grass and limiting the activities of many small fauna and insects. Surprisingly, forest officials as well as tourist department do not have any check on these tourism sports activities. So appropriate guidelines for tourism sports in Khajjiar meadow

Plate 3. Threat of Khajjiar Lake.

should be prepared. Tourists come to visit Khajjiar Lake through private vehicles and taxies because very little bus service is available to this area. Keeping in view, the disturbance created to the wildlife by vehicles in the form of horn, air pollution, noise pollution, etc. traffic laws should be strictly be implemented on all the vehicles entering the sanctuary area.

Stray animals enter the deep forests which affects the undergrowth of forest. Sometimes tourists also enter the forest and carry plastic materials with them. Entry of stray animals and of tourists into the forest patches should be restricted.

Khajjiar area has various endangered faunal species. Multiplication and breeding of threatened species of fauna through modern techniques of tissue culture and biotechnology should be encouraged. Also, conservation pockets for the rare and endemic faunal species found in Khajjiar area should be established. There should be documentation of local resources and support for threatened species. There should be inventorisation and monitoring of processes adversely impacting biodiversity. As a complement to *ex situ* approaches, *in situ* measures for biodiversity conservation can be developed. There should be efforts for restoration of degraded habitats and recovery of endangered species. All these measures can be implemented by promoting scientific and technical cooperation among Himalayan researchers. Various researchers are working on different aspects of ecology and biodiversity in isolation, there should be a convergence of this work.

When we implement all these conservation measures, there will be impact on the life of the local villages of the area. This lake is one of the income sources for the people as they cannot access forest produce in the wild life sanctuary. So a proper redressal of grievances should be put in place. To start with, there should be educational and public awareness programmes with respect to conservation and sustainable use of biodiversity. Economically and socially, sound measures should be adopted that act as incentives for conservation and sustainable use of components of biodiversity. These programmes should be undertaken among rural people, farmers and shepherds. Alternate grazing ground should be developed to help the poor rural people and shepherds.

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The pattern and cost of carnivore predation on livestock in maasai homesteads of Amboseli ecosystem, Kenya: Insights from a carnivore compensation programme

Moses Makonjio Okello[1]*, Richard Bonham[2] and Tom Hill[2]

[1]SFS Center for Wildlife Management Studies, Kenya, P.O. Box 27743- 00505 Nairobi, Kenya.
[2]Big Life Foundation, Kenya. P. O. Box 24133 - 00502, Nairobi, Kenya.

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Several papers have been written on the experiences, successes and challenges facing compensation schemes for wildlife, some of whom criticize the strategy while others support it. What is clear among the Maasai is that the burden of conserving wildlife, particularly predators that roam freely on their land and predate upon their livestock, is too great to bear: support in terms of financial compensation and mitigation strategies to reduce socio-economic loss from livestock deaths would help communities tolerate predators, and discourage some among them to kill carnivores in retaliation. Such programs in the Amboseli ecosystem are critical for the long term future of wildlife conservation. The Mbirikani Predator Compensation Fund (MPCF) is such a compensation scheme administered by the Big Life Foundation since 2003. Data from Big Life Foundation's monitoring records of compensation paid between 2008 and 2012 were analyzed in order to establish insights into the pattern and cost of predation in the Amboseli ecosystem. Results show that predation has been increasing with time, especially in recent years and during droughts; it is widespread across the Amboseli Ecosystem, but the frequency and intensity is higher near protected areas. The most common predators in the area studied are hyena, jackal, cheetah, lion and leopard; hyenas are the major predators, targeting all livestock types, while lion primarily target cattle. Between 2008 and 2012, more than KSh28 million was spent on compensation for over 9,000 livestock killed in bomas only. Poor Maasai homestead (*boma*) maintenance encouraged predation further. We recommend the compensation scheme to continue so that it cushions the Maasai from predation costs. Also, current measures of predation prevention such as improved livestock husbandry, construction of predator proof fences, and vigilance at night by the Maasai (especially the morans) should be encouraged, as it is within the MPCF. Benefit systems that complement predator compensation, such as generation of local employment, educational opportunities and involvement in carnivore conservation strategies, will help to conserve predators in the Amboseli ecosystem.

Key words: Amboseli ecosystem, human-carnivore conflict, compensation scheme, cost of conservation.

INTRODUCTION

Lions (*Panthera leo*) and other carnivorous species are in decline throughout most of their range in Africa due to persecution by humans related to depredation of livestock, lack of sufficient natural prey, diseases and destruction of their prime hunting habitats and human encroachment.

There are several mitigation strategies used to minimalize human - carnivore conflicts, but one strategy, compensation, has elucidated much debate on usefulness as well as constraints (Maclennan et al., 2009). Predation on livestock, other than causing general insecurity to human life, leads to huge economic losses, and a heavy conservation cost to local communities, particularly among poor countries. To help mitigate this conflict across a range of social and economic circumstances, livestock compensation schemes have been set up in several countries around the world in order to reduce costs to communities (Montag and Patterson, 2001).

Kenya, Botswana, Malawi and Zimbabwe are examples of the few African countries that have implemented state-run compensation schemes in the last few decades. However, other than government-sponsored compensation schemes, there has been various smaller-scale ‘‘direct incentive’’ schemes which do not necessarily compensate the losses at full market rates, but as “consolation” schemes that aim at increasing local tolerance of large carnivores by the local communities. In the Amboseli Ecosystem, the success of the MPCF has been evaluated (Kenana and Mwinzi, 2010); it was found that there is huge local support for the MPCF program, and that it has led to a much wider tolerance of carnivore costs, with less persecution, leading to an overall increase in carnivore numbers where the compensation scheme has been implemented.

The Amboseli Ecosystem hosts one of the largest remaining free-ranging, contiguous lion populations (IUCN, 2006). The Amboseli Maasai have a long history of lion killing (Western, 1982; Lindsay, 1987). Carnivore killings can either be cultural: when Maasai are coming-of-age ritual that brings prestige to the warrior who first spears the lion (Hazzah et al., 2009); or retaliatory (*Olkiyioi)* killings carried out in retaliation for livestock depredation.

Whilst the majority of lion killings were traditionally due to cultural reasons, most killing today, in the Amboseli and elsewhere in Africa is mainly for protection of life, livestock and in retaliation for losses thereof. If we can deal with compensation aspects to reduce anger and desperation due to predation, it is likely that local communities will tolerate carnivores and allow them to move freely and support minimum viable populations.

Due to the high costs incurred locally from conservation (such as depredation of livestock), and especially where there has not been intervention of compensation schemes and public awareness of the importance of carnivores for the tourism industry and ecology of the area, most Maasai have lost much of their former tolerance of wildlife that allowed them to coexist with large carnivores such as lions, and the availability of cheap and effective poison now gives them the means to eliminate predators. For example, between 1991 and 1994, lions were extirpated from Amboseli National Park, mainly through poisoning, but with time, they gradually recolonized from surrounding communal lands (Hazzah 2009).

In addition, in the early 2000s, conservationists and tourism operators documented unusually high numbers of lions being speared and poisoned on group ranches (communally owned traditional Maasai grazing lands) around Amboseli. In today’s Kenya, wild animals outside of protected areas have minimal positive economic value; they are only an expensive nuisance to the people who lose crops, livestock, and occasionally human life (Hazzah et al., 2009).

The reversal of this unsustainable situation requires poor rural communities, which carry the conservation burden of large carnivores, to be supported through compensation schemes and other benefit mechanisms of ecotourism through national level policy reforms that allow rural people to profit economically from ecotourism or other wildlife-based enterprises (Borgerhoff Mulder and Coppolillo, 2005). For example, properly managed ecotourism investment and activities, with profits transparently distributed to community members, could generate significant income and attendant good will towards wildlife. Kenya does not support trophy hunting for lions and large carnivores due to the potential to abuse the program; it has contributed significantly to declines in carnivore numbers where hunting has been introduced but is uncontrolled, or based on poor understanding of effects on population numbers and structure. Further, a shift towards a decentralized conservation agenda that empowers local communities to conserve wildlife could help address the burden of wildlife property damage to local communities and help turn wildlife conservation from a liability to an asset.

In the Amboseli region, the future of carnivore conservation depends primarily on a better understanding of the nuances of human-carnivore conflict and a concerted effort to address appropriate cultural and community-level institutions, ensuring that economic benefits are provided to local people who engage in conservation activities so that the costs incurred through livestock deaths are reduced. The overall objective of this research is to gain insights from long term monitoring data on human - carnivore conflicts, particularly insights into the pattern and nature of predator attacks to domestic livestock within Maasai homesteads (*bomas*) of two group ranches in the Amboseli region between 2008 and 2012 and to explore the means through which such conflict may be prevented and related costs reduced. Our

*Corresponding author. E-mail: mokello@fieldstudies.org or mokello33@gmail.com.

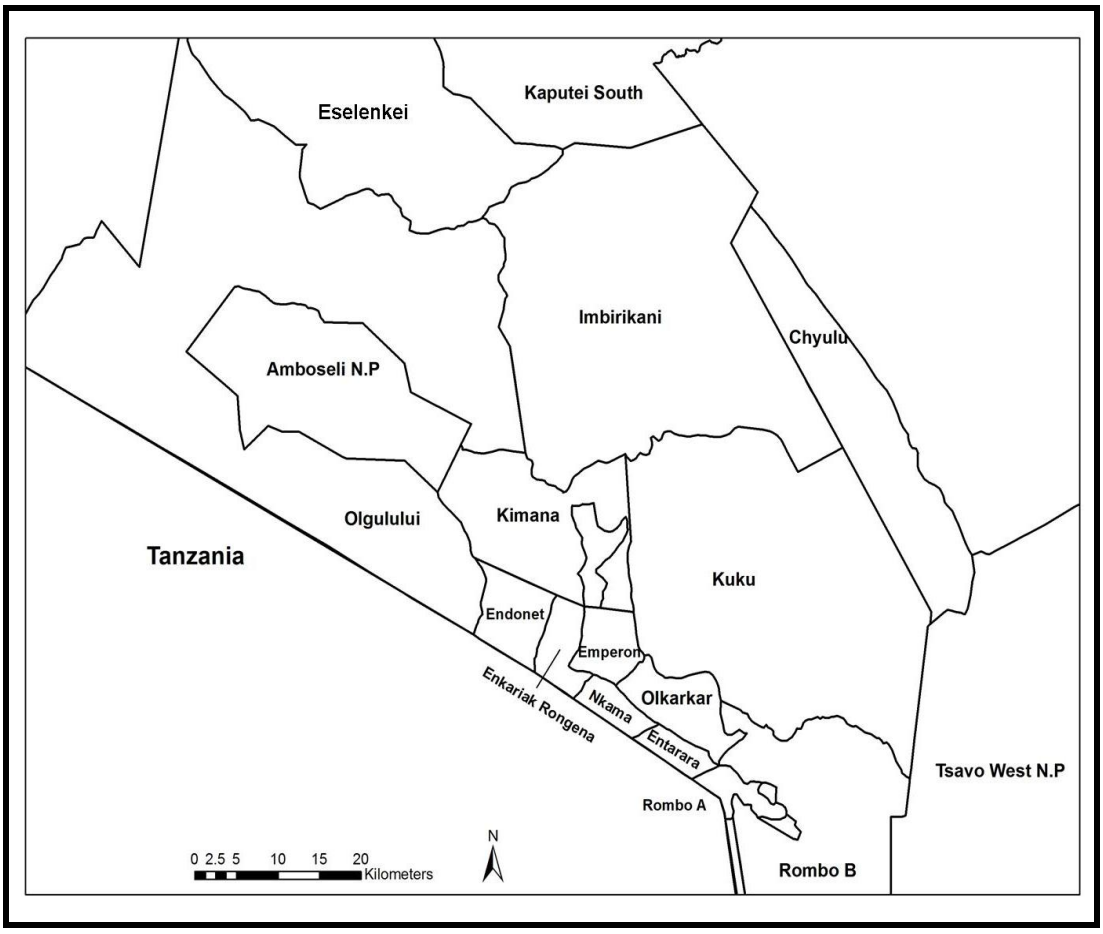

Figure 1. Amboseli and surrounding private and communal Maasai group ranches in Southern Kenya.

synthesis is particularly focused on the costs and pattern of carnivore predation and on the compensation scheme implemented by Big Life Foundation for incidences within bomas only. Insights from this work emphasize the importance of such schemes in contributing to monitoring human-carnivore conflicts, and provide us with assessment of the impact that compensation schemes supporting poor local communities can achieve, and the scale on which they can achieve it, in creating tolerance for large carnivores and giving them a chance for establishing viable populations especially outside the network of protected areas.

MATERIALS AND METHODS

Study site

The Tsavo-Amboseli ecosystem (Figure 1) in Southern Kenya is a major block for wildlife conservation and covers over 6,500 km^2 where large mammal species move freely in an area communally owned by the Maasai (Wishitemi and Okello, 2003). Home to renowned national parks such as Tsavo East and West, Chyulu and Amboseli, the ecosystem comprises an important area for ecotourism which provides a significant source of foreign revenue for Kenya (Okello et al., 2005). Despite being one of Kenya's smallest parks (392 km^2), Amboseli National Park is an extremely popular tourist destination and generates major revenue, while Tsavo (21,812 km^2) comprises the largest protected wildlife area in Kenya. The corridor of land between Tsavo and Amboseli National Parks serves as a wet season dispersal area for many wildlife populations, making it a crucial area for the global conservation of predatory species such as lion, and for East African wildlife conservation in general.

The rangelands in the area include a variety of habitats such as dense and open shrubland, bushland, and woodland, with both riverine and drier regions dominated by *Acacia* species. Soils in this region are classified as volcanic soils which are generally highly saline and alkaline. Whilst soils near water sources can be extremely fertile (Katampoi et al., 1990), in general the land is suitable only for pastoralism and wildlife grazing.

The unprotected corridor of land between the national parks comprises six group ranches: Kuku, Kimana, Mbirikani, Olgulului-Ololorashi, Eselenkei and Rombo group ranches, all situated in the Oloitokitok Sub County (Figure 1). These group ranches were set up in 1979 to protect the Maasai from losing more land than had already been lost to British colonials and other Kenyan ethnic tribes (Campbell et al., 2000). Kuku Group Ranch covers an area of 960 km^2, Kimana Group Ranch an area of 251 km^2, Olgulului - Ololorashi Group Ranch covers an area of 1,232 km^2, while Mbirikani Group Ranch covers 1,229 km^2. These group ranches

host privately-owned and community wildlife sanctuaries and therefore support the dispersal of wildlife populations between parks as well as supporting large non-migratory populations.

Traditionally, Maasai pastoralist practices have been compatible with wildlife due to large areas of land being available to share between livestock and wildlife, and range similarity in feeding strategies between livestock and most large herbivores. However, the harmony between Maasai pastoralists and wildlife has gradually diminished. The last census estimated the group ranches to have a density of 36 people per km^2 (Republic of Kenya 2001), with the Oloitokitok District having an estimated population growth rate of 5.6% compared to the national average of about 3.6% (Ntiati, 2002); this increasing population has intensified pressure on resources such as land and water (Newmark, 1993). At the same time, there has been a shift in the definition of wealth by the Maasai; originally defined by the number of children and livestock, wealth now depends more on cash and area of private land (Campbell et al., 2000).

These changes increase pressure on group ranches to subdivide their lands from communal to individual ownership. Current government polices provide a framework for this subdivision of land (Graham, 1989; Galaty, 1992); all Maasai group ranches have begun the process, with Kimana already fully subdivided. However, land subdivision results in the Maasai no longer being able to support their large herds of livestock without depletion of land resources. In response, many Maasai are becoming agro-pastoralists (Okello, 2005) despite their traditional belief that to till the land is a curse (Seno and Shaw, 2002). In addition, land tenure policy promoting land subdivision and private ownership has increased the opportunity for migrant farmers to lease subdivided land, hence accelerating agriculture expansion in the area (Okello 2005).

Except in the areas near Kilimanjaro where rain-fed agriculture is possible, almost all agriculture that takes place in the region requires the use of irrigation; this reduces the amount of water available for other land uses such as pastoralism and wildlife grazing (Campbell et al., 2000). In fact, cultivation is considered one of the most serious threats to wildlife conservation in this region (Pickard, 1998; Okello and Kiringe, 2004). The shift from pastoralism to cultivation has also increased conflict between wildlife and communities, through both the reduced ability of wildlife to find natural sources of food (resulting in increased dependence on crops and livestock) and the general damage of property as populations move through settlements. The conflict between humans and species which predate upon livestock is a crucial issue to address in order to sustain carnivore conservation whilst supporting local communities.

The history and process of MPCF predator compensation in the Amboseli ecosystem

The Amboseli-Tsavo Game Scout Association (ATGSA), a privately organized community law enforcement group that collaborates with the Kenya Wildlife Service (KWS) to protect wildlife, began recording the incidents and circumstances of lion killings in the Amboseli region in 2001, providing vital information of imminent regional lion extinction that, in turn, led in 2003 to the establishment of the Mbirikani Predator Compensation Fund (MPCF). MPCF was founded by and is administered through, the Maasailand Preservation Trust (MPT), now re-branded as Big Life Foundation (BLF). The MPCF is funded by private donors and collects long term monitoring data on human - carnivore conflicts and a participatory compensation program to reduce incidences of retaliatory killing of predators when domestic livestock is depredated.

The idea of a compensation fund to protect predators was originally proposed by Maasai community leaders themselves. The specific rules and regulations of MPCF were determined by mutual agreement between the Mbirikani Group Ranch Committee and MPT/BLF and formalized in a legally binding agreement (which, at present, contains 28 separate clauses concerned with verification requirements, benefits to be paid in arrears if no lions are killed, and penalties to be imposed if predators, lions in particular, are killed in violation of MPCF's rules). MPCF's terms and conditions can be re-negotiated annually but BLF reserves the right to terminate the project at any time (Figure 2). All operational costs and 70% of the livestock claims payments are borne by MPCF, while the group ranch covers 30% of the livestock claims payments, this money being earned mainly from bed night conservation fees paid to the community by the local Ol Donyo Lodge.

The predators protected by MPCF include lions, cheetahs (*Acinonyx jubatus*), leopards (*Panthera pardus*), spotted hyenas (*Crocuta crocuta*), jackals (*Canis mesomelas*), and the smaller cats. Cape buffalo (*Syncerus caffer*) and elephants (in collaboration with the Amboseli Trust for Elephants) are also included in the compensation scheme if and when they kill livestock. Maasai livestock species protected by MPCF are cattle, goats, sheep and donkeys.

MPCF has, from the outset, "lagged the market", with payments based on market prices lower than the present reality, although MPCF and the ranch community occasionally revise the values to be paid for each species of livestock protected, based in part on changing market prices. Further reductions in the amount paid by MPCF for a particular claim are based upon whether the depredation was by hyenas, whether a *boma* fence meets minimum standards of protection, and/or whether the head of livestock in question had been lost in the bush and was therefore unprotected altogether. If the predator was a hyena, only 50% of full payment is made; if a *boma* fence (for livestock killed inside a *boma* only) is less than four feet tall and four feet thick, or generally of poor quality, only 30% of full payment is made. If the livestock in question is judged to have been lost in the bush and unattended, only 50% of full payment is made; if a cow is lost in the bush and killed by a hyena, only 25% of full payment is made. If the livestock in question is killed outside the boundaries of the group ranch by more than one kilometer, no payment is made. If the carcass or tracks have been tampered with, or there is no carcass, no payment is made. If the livestock depredated does not belong to a group ranch member, no payment is made. The purpose of these rules is to discourage false claims and to severely punish those livestock owners who practice poor animal husbandry (Richard Bonham and Tom Hill, *personal communication).*

According to the agreement, if a lion is killed in violation of the rules of MPCF, those responsible are arrested and the family of each warrior involved in the killing is fined the value of a cow. At the same time, for the two-month period in which the lion killing took place, all otherwise verified compensation claims payments are rendered null and void for the group ranch members living in the geographic "zone" in which the lion was killed. The stated purpose of MPCF's penalties, according to BLF, is to create peer pressure among families and neighbors in each geographic zone of the group ranch to ensure that all members of the community cease retaliatory lion killing. These penalties have all been successfully imposed.

If an owner is unhappy with a particular verification of depredation on his or her livestock (conducted by the MPCF team of verifying officers, half of whom are not local Maasai), he or she can make a formal complaint to an MPCF Advisory Committee that meets six times a year (on every MPCF payday) which comprisesof one elected male elder from each geographic zone and two women who represent the female population of the community. During these meetings, with the complainant and the verification team in attendance, this committee decides the legitimacy of the complaint and advises MPCF as to whether the payment in dispute needs to be revised or rejected altogether.

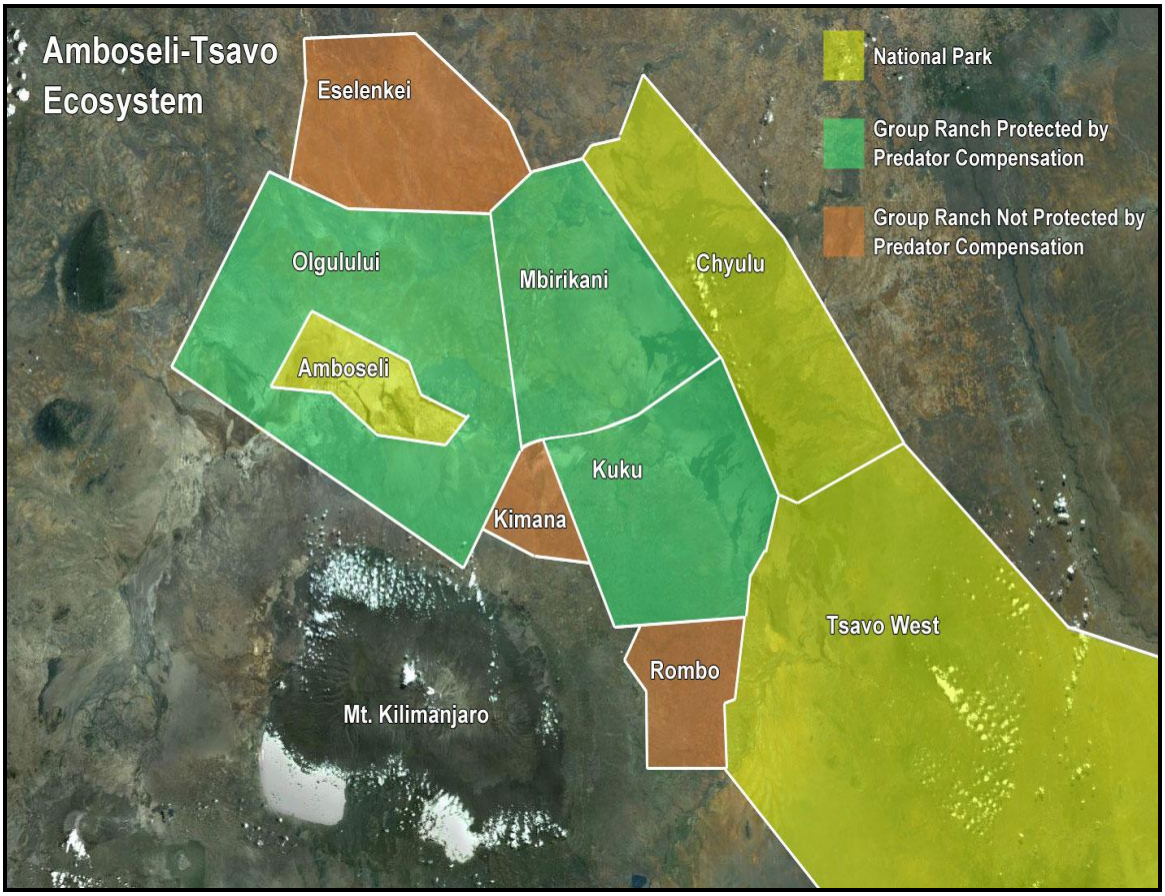

Figure 2. Group ranches where the MPCF is being implemented in the Amboseli Ecosystem.

As a result of the comprehensiveness of the scheme, over the entire history of MPCF, only 42% of full payment (lagging market price) on average has been made per claim (Table 1); therefore, MPCF has been designed from the outset to be a partial consolation fund only, one that rewards good animal husbandry and not one that can be exploited to excess by livestock owners for inordinate benefit (Richard Bonham and Tom Hill, personal communication).

According to data provided by Big Life Foundation, the rate of lion killing on Mbirikani Group Ranch for the 18 months prior to the introduction of MPCF in 2003 was 1.2 lions per month (or approximately 14 lions per year), by both spearing and poisoning. In the 11 years since the introduction of MPCF, a total of just six lions have been recorded killed on Mbirikani in violation of MPCF rules, a reduction in the rate of lion killing, when compared to the 18 months prior, in excess of 95%. The lion population that inhabits Mbirikani Group Ranch has increased significantly during the years MPCF has been in force.

This impressive positive contribution of the compensation scheme was achieved simply at a minimal costing of $10 per person per year (in 2013) when one considers the total cost of MPCF (all claims payments and all administrative, operational, and personnel costs) in relation to the total number of residents of Mbirikani Group Ranch. The approach of the MPCF is similar to an insurance scheme but instead of those covered by the program paying a nominal premium, their “payment” for the protection they receive is made in the form of behavioral change - ceasing the killing of lions and all other predators protected by the scheme, and helping to enforce the rules of MPCF on family members and neighbors.

In 2007 Kuku Group Ranch introduced a highly similar compensation program called *Wildlife Pays* (administered by Maasai Wilderness Conservation Trust); in 2008 Ogulului Group Ranch adopted MPCF with BLF as its administrator. Kenana and Mwinzi (2010) have reported that on this ranch, lion spearing and poisoning declined from 50 lions killed to only 1 lion after compensation was began. Altogether, a one million acre corridor of contiguous group ranch land is now protected by a predator compensation scheme (accounting for all major species of predators and livestock) that connects Amboseli National Park to Tsavo National Parks and the Chyulu Hills National Park, in which more than 40,000 Maasai are resident (Figure 3).

Methods

Here we report on five years of MPCF’s long term data collected between 2008-2012 (for Olgulului) and 2010-2012 (for Mbirikani) following the protocols described in the compensation process in this paper. This data was only for predation that occurs inside *bomas* (this accounts for only 20% of the total livestock depredations by carnivores). We therefore clarify that this is only a portion of the compensation paid by MPCF since it also covers livestock depredated outside of bomas.

Long term data used in this work was provided by BLF and consists of records of carnivore attacks on livestock reported by

Table 1. Payment amounts for carnivore predation by the compensation scheme and how payment amounts have changed over the years. The units are in Kenyan Shillings.

Year	Livestock type	No penalties		Lost in the bush		Inadequate boma construction	
		Lion, Cheetah, Leopard	Hyena, Buffalo, Jackal	Lion, Cheetah, Leopard	Hyena, Buffalo, Jackal	Lion, Cheetah, Leopard	Hyena, Buffalo, Jackal
2003-2008	Cow	13,500	6,750	6,750	3,375	4050	2025
	Donkey	6,000	3,000	3,000	1,500	1800	900
	Shoat	2,000	2,000	1,000	1,000	600	600
2008-2010	Cow	14,500	7,250	7,250	3625	4350	2175
	Donkey	6,000	3,000	3,000	1500	1800	900
	Shoat	2,500	2,500	1,250	1250	750	750
2010-2014	Cow	20,000	10,000	10,000	5,000	6,000	3,000
	Donkey	7,000	3,500	3,500	1,750	2,100	1,050
	shoat	3,000	3,000	1,500	1,500	900	900

members of Olgulului from 2008 to 2012, while the data for Mbirikani Group Ranch was available from 2010 to 2012. Only reliable and verified data was used in this analysis and the mentioned years provided the best data for each of the group ranches included in this assessment. This paper considers only the livestock killed and fully compensated for. When incidences of predation are reported, data on the carnivore species, livestock species, location, structural condition of the *boma* (whether well maintained to deter predators or not), date and amount paid off in compensation are recorded in a standardized form. The compensation procedure follows events outlined in the schematic diagram below (Figure 3). Visual assessment of the state of the boma (broken places, age of the fencing materials, types of fencing material and status of poles of the fences) was used to classify bomas as either *well maintained* or *not well maintained*.

Monitoring data collected information on what species of livestock was killed, how many were killed in an attack incidence, which predator species was involved, what was the date of the attack, how much money was compensated based on existing protocol, state of the homestead fence, GPS location, and the name of the area where the attacks took place.

Data was analyzed using normal mathematical procedures of measures of central tendency such as means and dispersion such as standard error (Zar, 1999). Relationships between attributes for count data were analyzed using Chi-square cross-tabulations, while analysis for trends used spearman non - parametric correlation (Zar, 1999). Any significant differences between averages were established using One Way Anova. All tests were deemed significant statistically if the probability of Type 1 error (alpha) was less than 0.05. Tallies and data processing and analysis were completed using Excel Microsoft Spreadsheet 2000 and the SPSS statistical package 2001.

RESULTS

Between 2008 and 2012, a total of 4,660 carnivore predation incidences were reported in Olgulului Group Ranch, involving about 7,491 livestock deaths (an average of 932 incidences per year, involving an average of 1,498 livestock deaths per year). This resulted in a total compensation payment of KSh19, 144, 310 with an average payment of KSh4, 109 per incidence paid out for livestock predation. With regards to Mbirikani Group Ranch, there were 1,785 predation incidences (595 incidences per year, on average) involving 2,740 heads of livestock killed by predators (913 livestock deaths per year, on average). This resulted in a total compensation payment of KSh8, 812,375 with an average payment of KSh4,980 per incidence paid out for livestock predation.

In both Oglulului and Mbirikani, even though predation dropped after the 2009 drought, the general trend in predation claims, predation pressure and accompanying compensation costs showed a generally increasing trend over time. The increase in number of claims in Olgulului (Figure 4) was however not significant ($r = 0.30$, $p = 0.62$), but the increasing trend in livestock claims in Mbirikani (Figure 4) was significant ($r = 0.99$, $p = 0.001$). The increase in the total number of livestock killed by carnivores in Olgulului (Figure 5) was not significant ($r = 0.30$, $p = 0.62$), but the increasing trend in livestock claims in Mbirikani (Figure 4) was significant ($r = 0.99$, $p = 0.001$). Further, the increasing trend in compensation cost (Figure 6) in Olgulului ($r = 0.60$, $p = 0.30$), as well as in Mbirikani ($r = 0.50$, $p = 0.67$) were not significant.

In terms of the number of compensation claims for specific livestock types, goats and sheep (shoats) in both group ranches (Figures 7 and 8) were the animals which compensation claims were mostly demanded, followed by cattle and then donkeys in both Olgulului (Table 2) and Mbirikani group ranches (Table 3). The trend of claims for each livestock types in Olgulului (Figure 7) showed positive (increasing) but insignificant trend in claims for shoats ($r = 0.30$, $p = 0.62$), and donkeys ($r = 0.70$, $p = 0.19$), and negative (declining) but insignificant for cattle

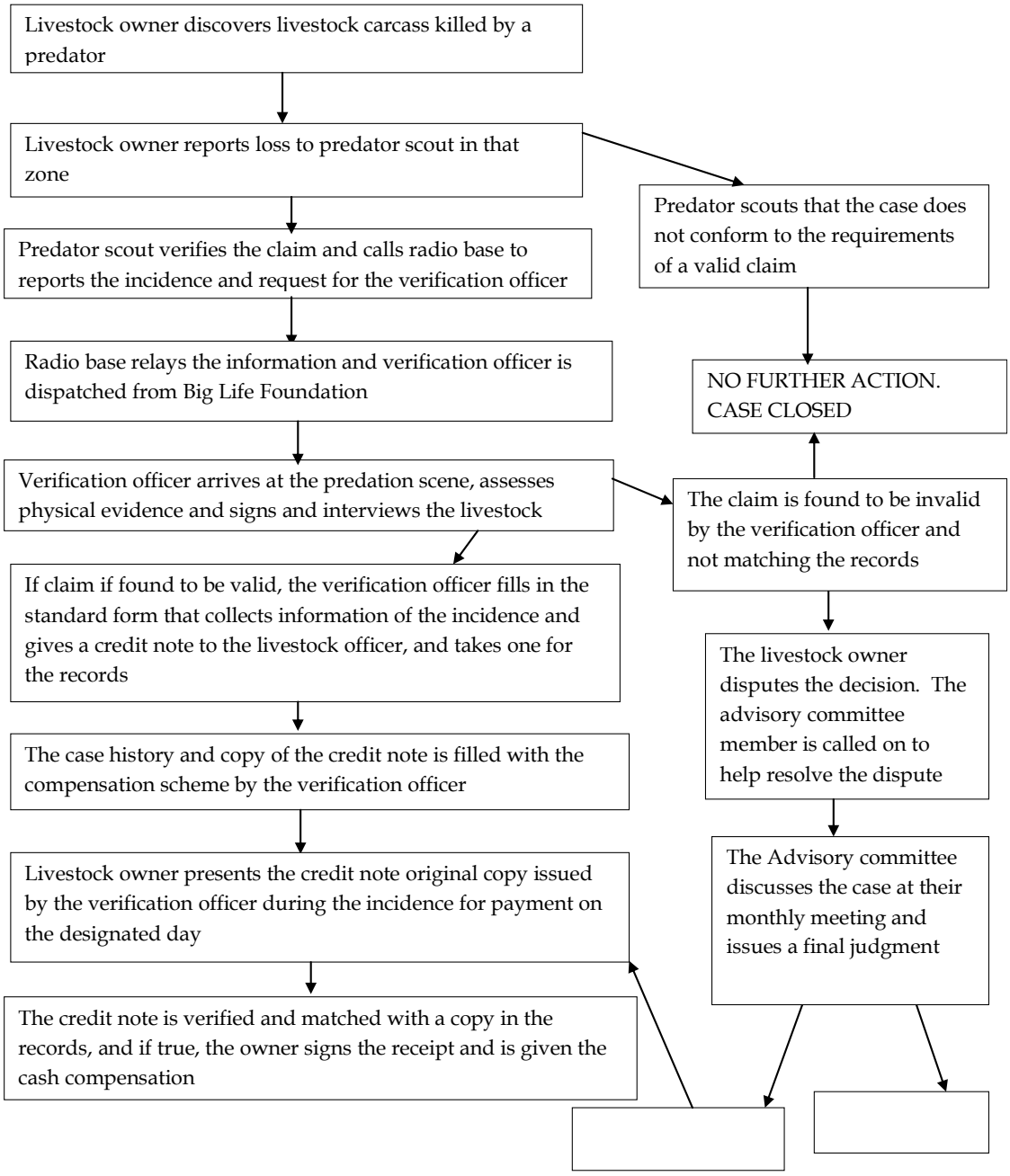

Figure 3. Schematic procedure on MPCF compensation scheme.

claims (r = -0.60, p = 0.29). However, the trend of claims for each livestock types in Mbirikani (Figure 8) showed positive (increasing) and significant trend in claims for shoats (r = 0.99, p = 0.001); but negative (declining) and insignificant for cattle (r = -0.50, p = 0.67), but negative (declining) and significantly for donkeys' (r = -0.99, p = 0.001).

In terms of total number of animals killed (animals killed per incidence reported), in Olgulului, shoats (average 1.71 ± 0.05, n = 3633 per incidence) were attacked in significantly higher numbers than other livestock (F = 15.87, df = 2, 4655, P < 0.001), followed by cattle (1.27 ± 0.27, n = 736) and comparatively fewer donkeys (1.13 ± 0.24, n = 289). In Mbirikani, a similar trend was observed, in which the average number of shoats killed (1.56 ± 0.05, n = 1621 per incidence) was also significantly higher (F = 5.22, df = 2, 1618, P = 0.005) than both cattle (1.21 ± 0.36, n = 232 per incidence) and donkeys (1.07 ± 0.05, n = 28 per incidence) (Table 4). These results may be due to either the relative

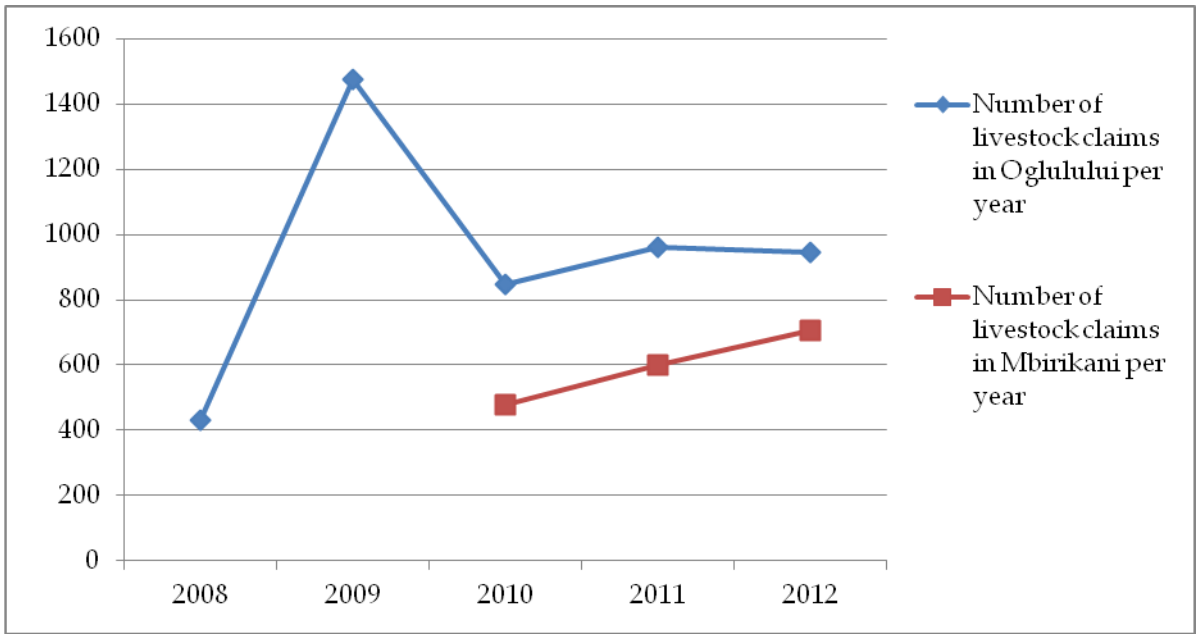

Figure 4. Total number of predation claims in Olgulului and Mbirikani.

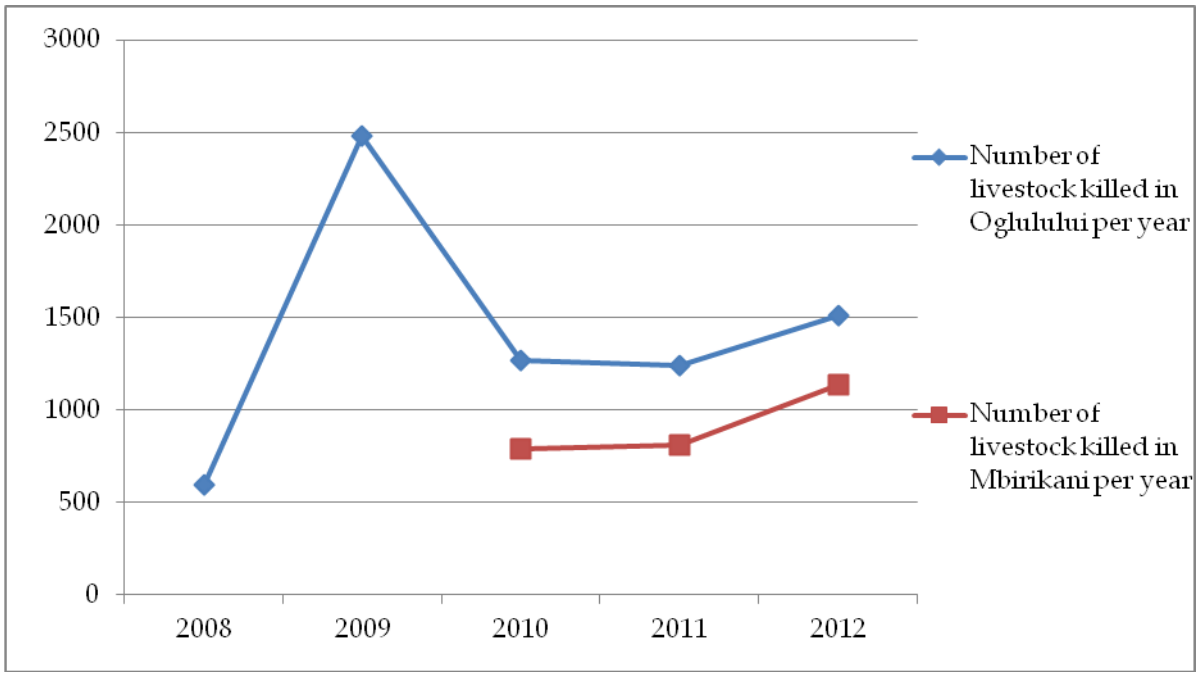

Figure 5. Total number of livestock killed in Olgulului and Mbirikani.

vulnerability of livestock types, preference by individual carnivore types or simply attacks in relation to availability (in numbers) of each livestock type (or a combination of the above).

Trends of the number of livestock killed by carnivores varied over time and between the two group ranches. In Olgulului Group Ranch (Figure 9), the trend in the numbers of shoats ($r = 0.40$, $p = 0.51$) and donkey ($r = 0.10$, $p = 0.87$) killed was positive (increasing) but insignificantly. However, the trend in the number of cattle killed in Olgulului was negative (declining) but insignificant as well ($r = -0.80$, $p = 0.10$). In Mbirikani Group Ranch

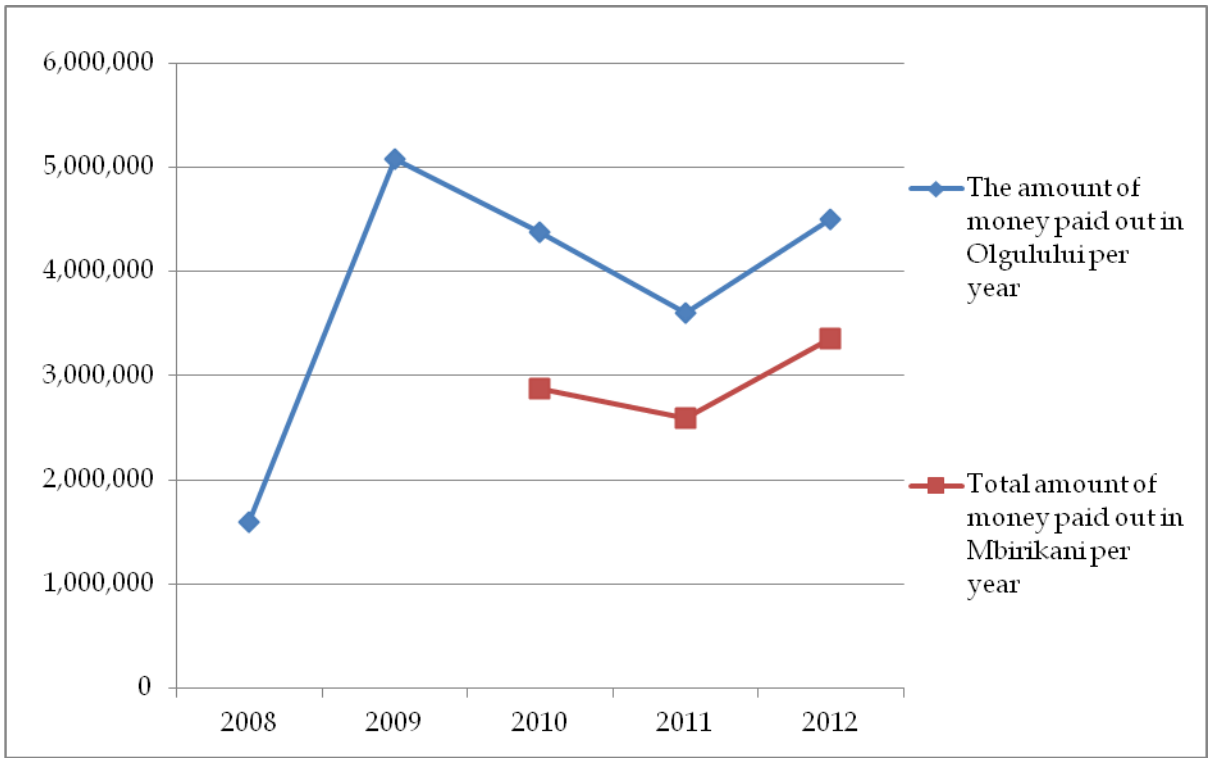

Figure 6. Total compensation payments (KSh) for livestock depredation in Olgulului and Mbirikani.

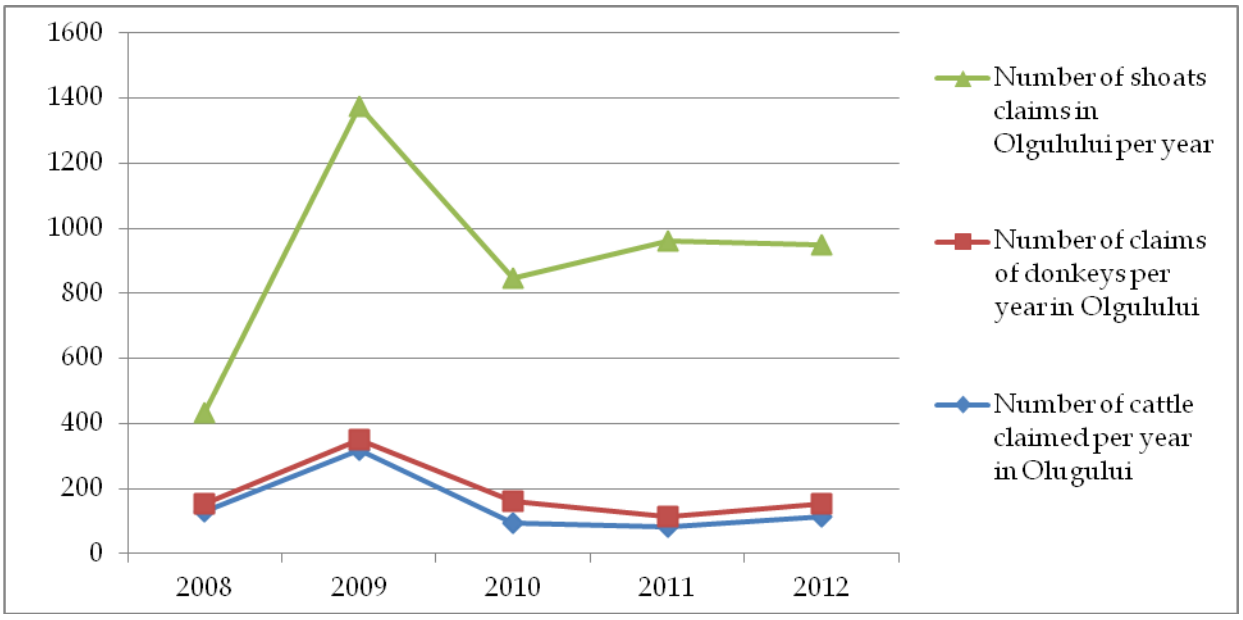

Figure 7. Total number of claims for different livestock types killed by carnivores in Olgulului.

(Figure 10), only the trend in the numbers of shoats killed was positive (increasing) and significant (r = 0.99, p = 0.001).

However, the trend in the number of cattle killed in Mbirikani was negative (declining) but insignificant as well (r = -0.50, p = 0.67), and negative (declining) but significant for donkeys (r = -0.99, p = 0.001).

Of particular note is the year 2009 and 2010 because

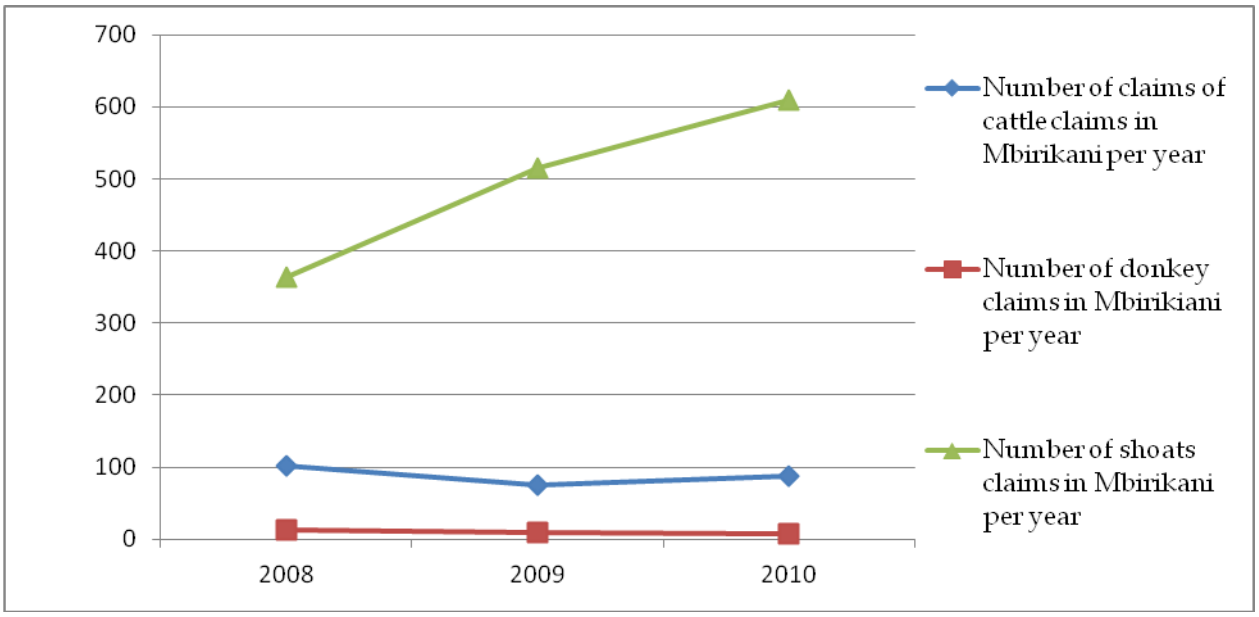

Figure 8. Total number of claims for different livestock types killed by carnivores in Mbirikani.

Table 2. The average amount of money and claims per livestock type killed by carnivores in Olgulului Group Ranch between 2008 and 2012.

Species	Livestock total	Number of claims	Average Mean ± SE	Total number of animals killed
Cattle	6,938,975	736	9,441 ± 319.22	934
Donkey	930,390	289	3,219 ± 175.84	326
Sheep and goats	11,274,945	3,635	3,102 ± 62.24	6,230

Table 3. The average amount of money and claims per livestock type killed by carnivores in Mbirikani Group Ranch between 2010 and 2012.

Species	Total cost (Ksh) spend	Number of claims	Number of animals killed	Average mean ± SE
Cattle	3,263,125	266	325	6190 ± 178.68
Donkey	149,100	30	32	4,468 ± 678.08
Shoats	5,400,150	1,489	2,383	45131 ± 136.88

Table 4. Portion of claims and expenditure for each carnivore type in Olgulului Group Ranch.

Carnivore	Number of claims Incidences	Total animals killed by predator	Total paid (KSh) over 5 years	Average cost per claim (mean, SE)
Lion	637	855	5,836,900	9,163.11 ± 372.89
Leopard	99	122	362,250	3,659.65 ± 382.93
Jackal	856	950	1,904,950	2,225.41 ± 38.60
Hyena	2,366	4714	9,046,510	3,825.16 ± 95.16
Cheetah	696	845	1,953,450	2,802.65 ± 83.61
Buffalo	5	5	40,250	4,106.01± 78.49

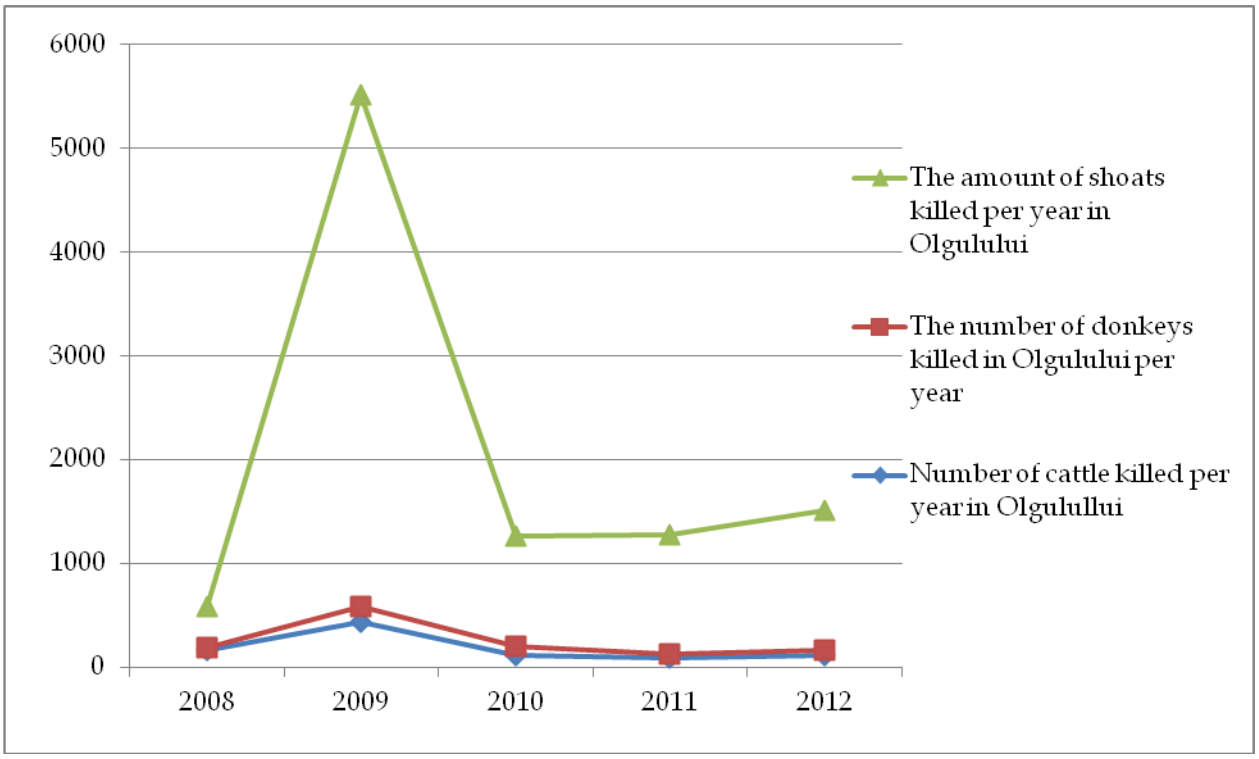

Figure 9. Total numbers of various livestock types killed by carnivores in Olgulului.

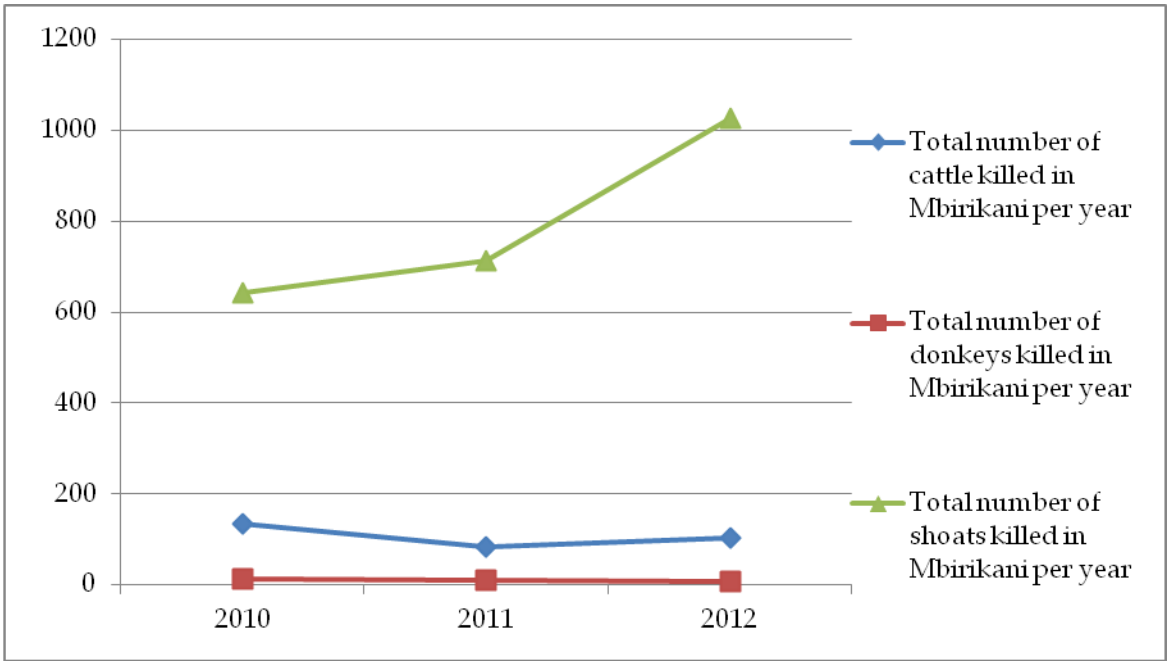

Figure 10. Total numbers of various livestock types killed by carnivores in Mbirikani.

there was a severe drought in Kenya that led to the decline or migration of most typical natural prey species, thus increasing predator dependence on livestock. Accordingly, for Olgulului most incidences occurred in 2009/2010. The total cost in compensation varied, being dependent not only on the frequency of attacks, but on

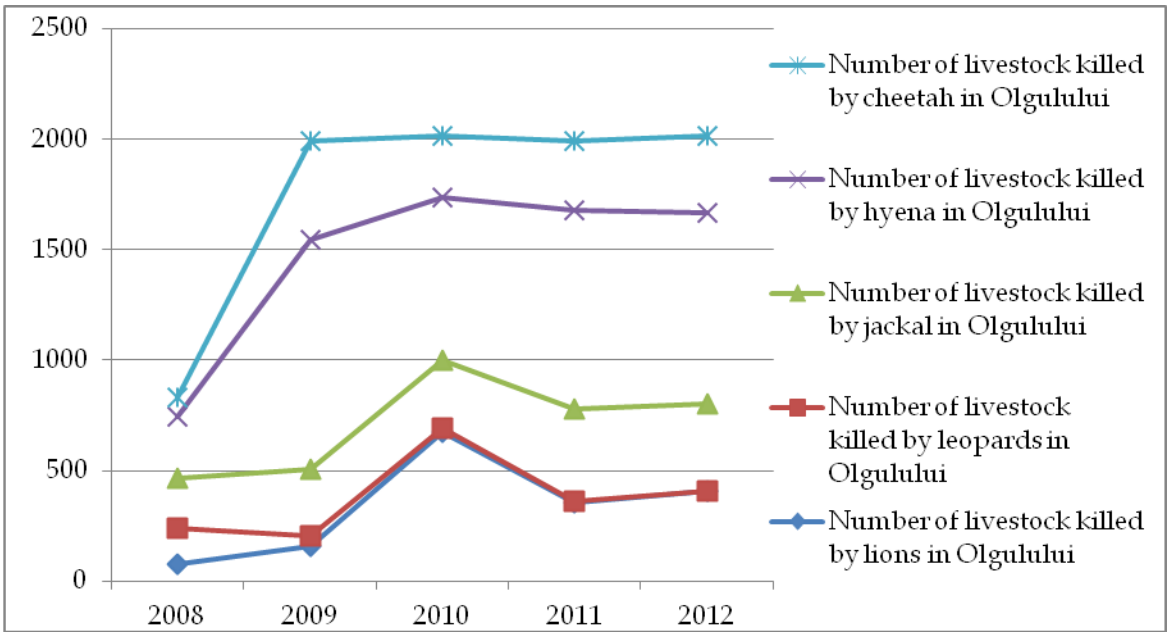

Figure 11. Predation intensity and trends for Olgulului Group Ranch.

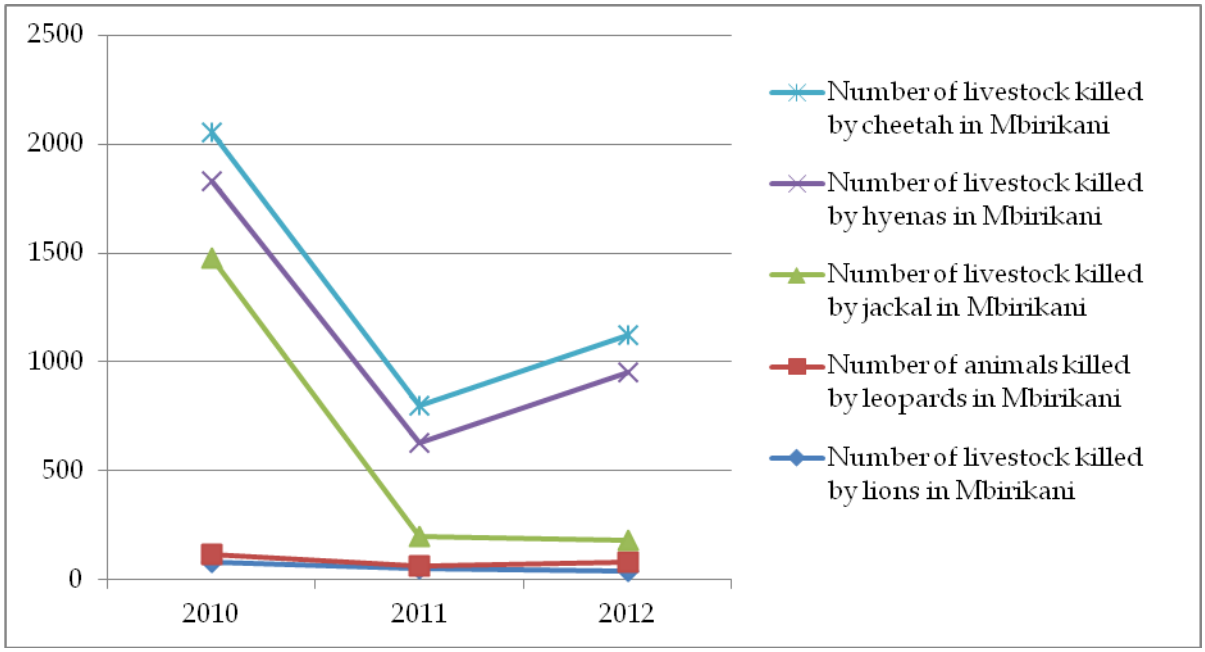

Figure 12. Predation intensity and trends in Mbirikani Group Ranch.

the number of animals killed and livestock type most targeted). It also depended on direct proximity to the conservation area. Olgulului / Ololorashi Group Ranch surrounds over 90% of Amboseli National Park perimeter and therefore predation frequency and pressure is generally high for all carnivore predation cases.

In terms of carnivores most involved in predation incidences (Figures 11 and 12) and associated compensation costs (Figures 13 and 14), hyena was the most problematic predator, followed by jackal, cheetah, lion and leopard (Tables 4 and 5), with some deaths by buffalo attacks. In Olgulului, the most common predators were hyena, jackal, cheetah and lion; however, in terms of total compensation cost, whilst the hyena caused the

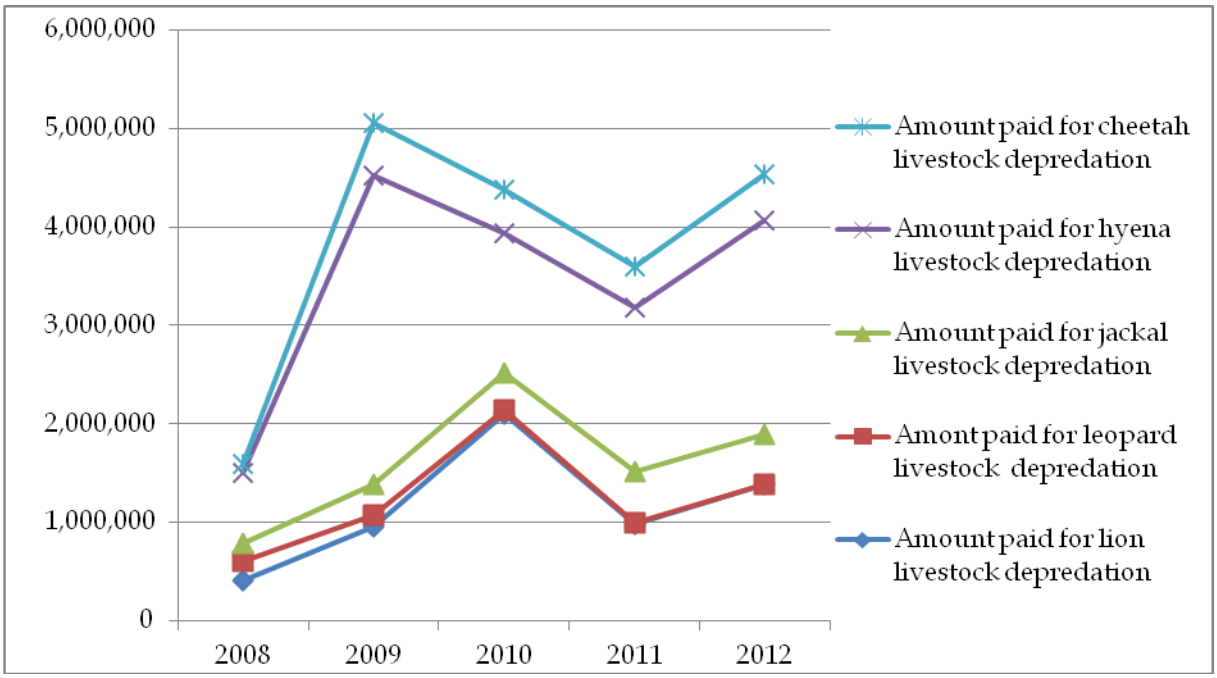

Figure 13. Predation trend and cost for Olgulului Group Ranch.

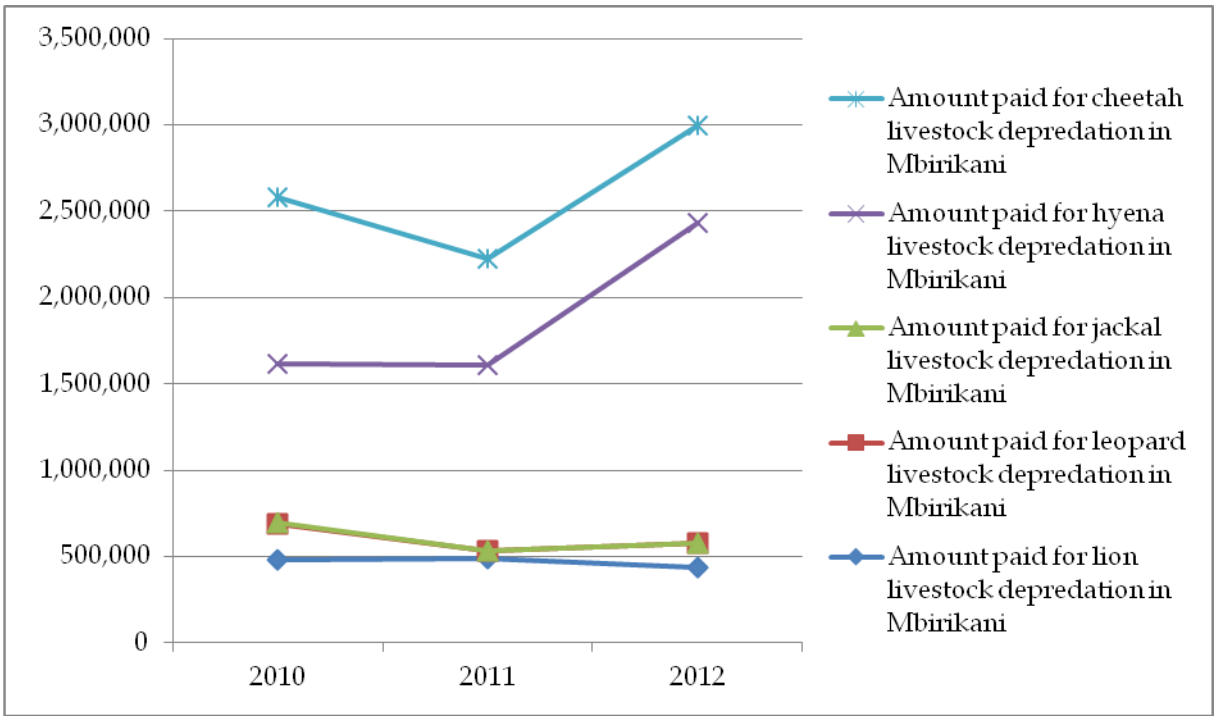

Figure 14. Predation trend and cost for Mbirikani Group Ranch.

greatest costs, this was followed by lion, cheetah, and finally jackal (Table 4). Similarly, in Mbirikani, the three main predators (in terms of both numbers of incidences and total number of livestock killed) were hyena, cheetah and jackal, whilst greatest contributions to compensation costs were due to the hyena, cheetah and lion (Table 5).

Trends in carnivore predation frequency were variable among the carnivore species and between the two group

Table 5. Portion of claims and expenditure for each carnivore type in Mbirikani Group Ranch.

Carnivore	Number of animals killed	Number of claims	Total Ksh paid	Average per claim ± SE
Lion	201	138	1,678,850	12,137 ± 920
Leopard	89	68	404,000	5,941 ± 609
Jackal	324	297	745,000	2,534 ± 66
Hyena	1559	844	3,848,875	4,609 ± 176
Cheetah	566	437	2,138,750	4,928 ± 237
Buffalo	1	1	900	-

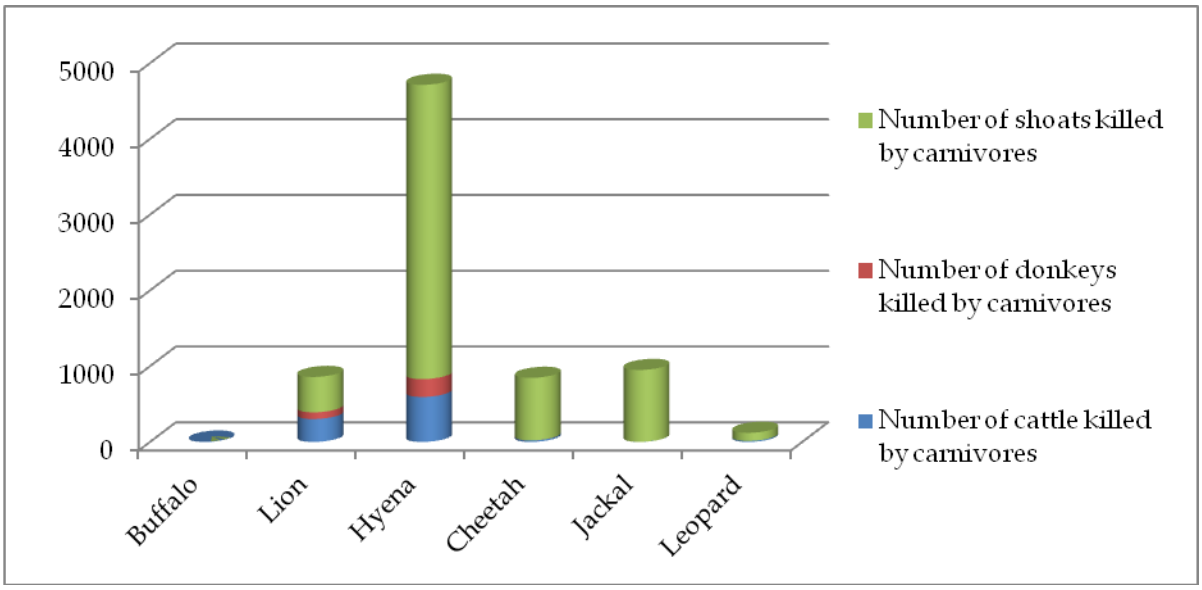

Figure 15. Number of livestock killed by various carnivores in Olgulului Group Ranch.

ranches. In Olgulului, incidences (and number of livestock killed) involving hyena, lion and jackal have generally increased, while those involving cheetah have remained stable and those involving leopard appear to have declined. Furthermore, it is evident that predation rates regarding jackal, hyena and cheetah were higher than for other carnivores during the drought period of 2009/2010 in Olgulului (Figure 11). In Mbirikani, however, lion, leopard, jackal and cheetah did not show a clear trend over time, with both incidences and number of livestock killed over time remaining variable (Figure 12). However, incidences and total livestock killed by hyena and cheetah seemed to increase with time in Mbirikani Group Ranch (Figure 10). Furthermore, the cheetah was involved in a relatively higher number of incidences and number of livestock killed during the drought period of 2009/2010 (although the same general trend with hyena) compared to other carnivores in Olgulului Group Ranch.

In terms of relationships between most vulnerable livestock species (regarding both incidences and number of livestock killed) and carnivore type, it appears that, in general, large predators such as lion and hyena consumed across livestock types, while relatively smaller and more specialized predators such as jackal and leopard targeted relatively small sized livestock prey only (Figures 15 and 16). This prey preference is evident in both Olgulului. Carnivore species preference seemed to also be influenced by livestock type and size, with relatively larger carnivores (lion and hyena) taking larger sized domestic prey (cattle and donkeys) while smaller sized carnivores (including jackals) targeted relatively smaller domestic prey types (χ^2 = 732.26, df = 10, P < 0.001). This prey preference was also similar in Mbirikani where predators seemed also to have prey preference (χ^2 = 311.88, df = 10, P < 0.001). Nevertheless, the cheetah seemed to prey upon both cattle and shoats; in Mbirikani, they prey exclusively on shoats in Olgulului. Since sometimes carnivore predation can be opportunistic, the general observation was that even though larger carnivores tended to attack large livestock frequently, smaller livestock prey such as shoats were attacked by all carnivore species, including large sized carnivores (lions and hyena).

In term of hotspots for human-carnivore conflicts, these

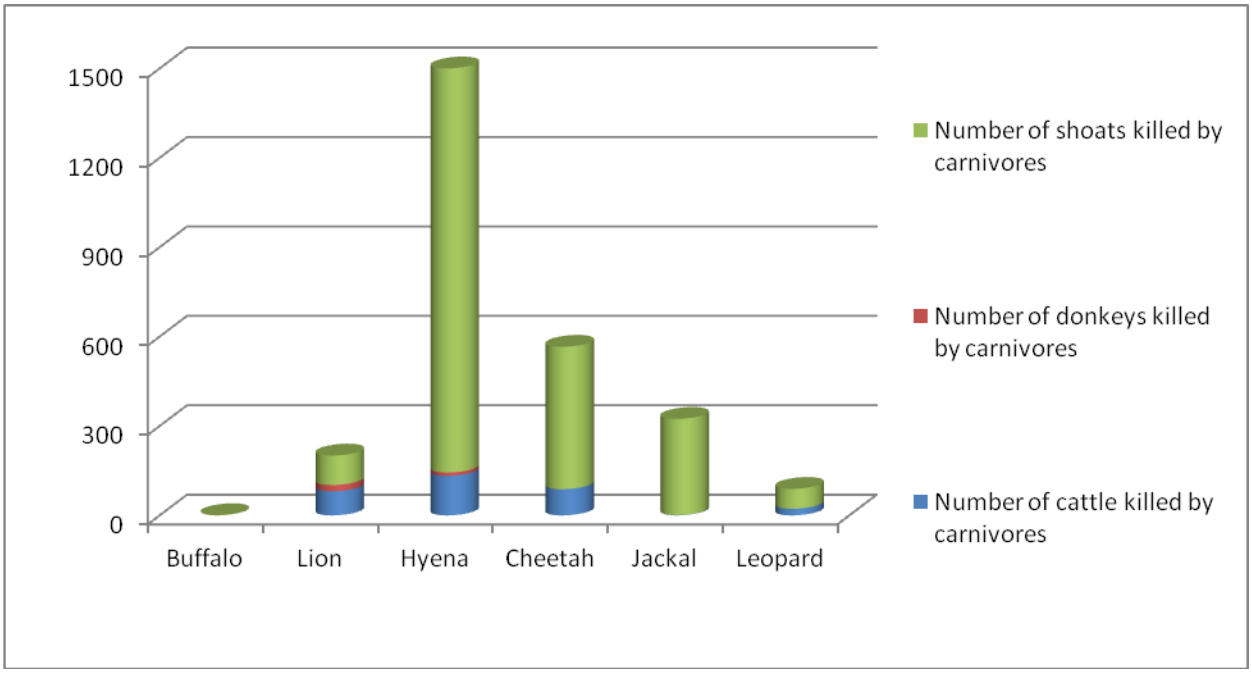

Figure 16. Number of livestock killed by various carnivores in Mbirikani Group Ranch.

are widely distributed in the Amboseli Ecosystem, with the greatest hotspots being in Olgulului / Ololorashi relative to Mbirikani Group Ranch. Most of these hotspots are relatively close to a national park, in isolated rangeland or near wildlife sanctuaries/conservancies.

The condition of the Maasai boma seemed to influence the frequency and intensity of attacks (in terms of number of animals killed), which supports the MPCF regulation of paying just 30% of the agreed rate if the boma is in disrepair compared to 100% compensation rate if the boma is well kept. In Olgulului, badly maintained bomas had a higher average number of livestock killed (average killed per incidence 1.91 ± 0.07, n = 2507) with significantly higher numbers killed ($F = 170.85$, df = 2, 4655, $P < 0.001$), compared to relatively well maintained ones (1.22 ± 0.07, n = 96) and well maintained bomas (1.25 ± 0.02, n = 2055).

Further, in Olgulului Group Ranch, livestock depredation was highly dependent on boma condition ($\chi^2 = 127.65$, df = 4, $P < 0.001$), with more predation taking place in poorly maintained bomas than in well maintained ones. This was also similar in Mbirikani Group Ranch, where more predation occurred in poorly maintained Maasai bomas ($\chi^2 = 95.38$, df = 4, $P < 0.001$) compared to moderately or well-maintained ones.

DISCUSSION

Carnivore conflicts are higher among the communities adjacent to protected areas than those that are far off. The results of this study show that Olgulului which surrounds over 90% of the perimeter of Amboseli National Park, consistently suffered a greater frequency and intensity of carnivore attacks to livestock compared to Mbirikani. This is expected as carnivores venture out of the safety of protected areas into neighboring dispersal areas first and will attack livestock that is grazing or in poorly protected Maasai homestead. Costs are likely to be very high if carnivore attacks to lost livestock or those in grazing fields are incorporated in the total cost assessments. It is therefore important to prioritize the communities adjacent to protected areas and wildlife sanctuaries for compensation, since they bear the greatest loss and cost of conservation from dispersing carnivores from core protected areas (Western, 1975, 1982; Galaty, 1992; Pickard, 1998; Seno and Shaw, 2002). These communities should also be prioritized for any other benefits or innovations aimed at reducing carnivore predation or human-carnivore conflicts in general. They should also be targets for awareness and education aimed at increasing the harmonious coexistence of communities and wildlife.

From MPCF records, Maclennan et al. (2009) concluded that, in descending order of importance, spotted hyena, lion, and cheetah and or leopards caused the greatest number of cattle losses. Our analysis has confirmed that the hyena still leads in frequency and intensity of predation; however, our data suggests that jackals are the next greatest predators, followed by cheetah, lion and leopard. The differences may be due to the fact that our data only considered predation in bomas

while his may have considered predation in the bomas and in the field as well. In terms of cost, the greatest amount of compensation was paid out for predation by hyena, followed by cheetah and lion. Hazzah (2009) noted that, compared to other large carnivores, lions are relatively insignificant as livestock predators and so the intense resentment of lions expressed by 25% of respondents suggest that conflict is rooted in perceptions rather than actual losses, possibly influenced by vulnerability linked to land use changes, displacement, and the imposition of conservation measures (Lindsay, 1987; Adams and McShane, 1996). However, this analysis shows that lions can be significant predators to livestock and, since they target cattle, which are highly priced both economically and socially, such incidents can cause more intense retaliation reactions than other carnivores (Dickman, 2005; Bagchi and Mishra, 2006). Lions are also more vulnerable to retaliatory poisoning because they often return to carcasses. Hazzah et al. (2009) noted that lions are most vulnerable because they are the easiest carnivore to kill using traditional methods (spearing), while leopard, hyena, and cheetah are much more difficult to track and kill; furthermore, spearing a lion has traditionally provided immense prestige within Maasai society (Hazzah, 2009).

In terms of compensation costs and carnivore attack incidences, shoats were the most affected by predation, followed by cattle and donkeys. There could be several explanations for this. First, shoats constitute the greatest number of individuals of these livestock, followed by cattle and finally donkeys. If the rate of carnivore attack is based on relative abundance and frequency of encounter, it therefore makes sense that attacks on shoats will follow the pattern seen (Holmern et al., 2007). Another possible explanation is the abundance of the carnivore types and their hunting strategy. Hyena appears to be the most abundant carnivore in the ecosystem (Kenana, personal communication) and because of its hunting strategy and its physical strength, it can easily take both small prey (shoats) and larger prey (cattle and donkeys) (Kissui, 2008). Therefore attacks by hyena are likely to depend on which livestock type is more readily available (Holekamp et al., 1997). Conversely, other smaller predators such as jackals, cheetah and leopard are likely to prefer smaller livestock prey than larger types, with their ability to overcome prey being the main influence on which livestock type they attack. These two reasons could explain the relatively higher rates of predation on shoats than on cattle and donkeys. Lions, on the other hand, may optimize their foraging reward by choosing bigger livestock prey such as cattle. Indeed lion attacks of cattle and donkeys are relatively higher than those by other carnivores (except hyena).

General predation in the group ranches appears to be increasing. This may be due to increasing carnivore and/or livestock numbers, thus increasing the rate of encounter which can lead to an attack. Indeed, the number of carnivores in the Amboseli ecosystem is increasing (Kenana, KWS; and Hazzah and Dolrenry at Lion Guardians, personal communication). It is therefore likely that an increasing predator population will not only predate on a higher number of natural prey, but a higher number of domestic prey as well (Patterson et al., 2004). Although no scientific studies have been done to show relative carnivore preference for livestock over natural prey once they begin taking livestock, a several predation cases in the region (in BLF's experience) have shown that once a carnivore begins to attack livestock, it may develop a preference for this meat over that of wild prey, since it is easier to kill and may have more tender meat, and may become a frequent predator of livestock. This may also become magnified in times of drought when there are lower numbers of natural prey, or at times when natural prey migrates beyond predator ranges, leaving livestock prey to become the primary target (Lindsay, 1987; Treves and Karanth, 2003; Treves et al., 2006). Indeed, the results show a clear indication that predation of livestock was greatest in the year 2009 when there was a general drought that reduced natural carnivore prey.

Another reason for increased livestock depredation may be continued human encroachment onto carnivore habitat. When numbers of livestock have increased in the Amboseli ecosystem, group ranch pasture (now declining in quantity and quality) has not been sufficient to sustain Maasai livestock. Encroachment into national parks (Tsavo and Amboseli) then becomes inevitable, especially during droughts, and lead to increased carnivore attacks, especially on stray livestock or those without a Maasai herder present (Hazzah et al., 2013;, IUCN, 2006; Saberwal et al., 1994; Krebs, 1999). Furthermore, increased livestock numbers necessitate larger and therefore less well maintained livestock sheds in bomas due to congestion and wear and tear of thorny fences. Natural thorny fence deterioration, especially in wet and damp seasons, increases fence decay and its inefficiency as a barrier (Kiringe and Okello, 2005), therefore increasing the likelihood of a successful attack by a predator.

The results clearly showed that bomas which were well maintained had reduced incidences of carnivore attacks compared with those that were poorly maintained. This emphasizes the need for proper boma fencing and strengthened security measures (such as additional night vigilance) as a deterrent to livestock predation (Okello et al., in press).

Responsible herding (by more experienced members of the community in addition to minors) and minimizing loss of livestock during grazing is also critical (Ogada et al., 2003). Tracing straying livestock and proper boma maintenance as well as support for the construction of predator proof bomas (carried out by Big Life Foundation, African Wildlife Foundation, African Conservation Centre,

Lion Guardians and other conservation organizations in the ecosystem) complements the compensation scheme and should be strengthened as a strategy to prevent predator attacks and reduce the number of incidents requiring compensation.

It is difficult to ascertain from the Maasai people whether or not the numbers of their livestock is increasing over time. Such an issue is sensitive, since it is a matter of individual wealth. However, personal observation estimates that recent droughts, especially that of 2009, reduced Maasai livestock numbers by over 60%. It is likely that livestock numbers are now recovering, hence the increase in predation.

Furthermore, land uses in the greater Amboseli ecosystem are changing fast, with increasing cultivation and urbanization coupled with high human immigration and birth rates, leading to diminishing space for livestock grazing (Woodroffe, 2000; Galaty, 1992; Okello et al., 2005; Campbell et al., 2000). This in turn leads to the confinement of grazing in areas where encounters with carnivores become high, hence increasing predation rates.

There are three possible interventions, in our view, that provide hope for carnivores in the Amboseli area: 1) the implementation of compensation schemes that help the Maasai to bear the costs of living with wildlife (such as BLF's compensation scheme studied here); 2) the empowerment of the Maasai to take simple and effective measures that reduce predation incidences on their livestock, such as the construction of predator proof bomas; and 3) the implementation of initiatives that diversify means for sharing benefits of wildlife across local communities, such as through employment in tourism or wildlife protection.

The strategy with the widest local appeal and support, one that has the greatest impact in reducing human-carnivore conflict and which covers the greatest number of people will make the greatest contribution to carnivore conservation. The compensation scheme as implemented now in Mbirikani is the most valuable, based on these criteria and on local opinions (Kenana and Mwinzi, 2010). These strategies, supported by KWS animal control units, should help to reduce human-carnivore conflicts and thus increase the tolerance of the Maasai in sharing resources with wildlife, ultimately serving to increase the number of key carnivores in the Tsavo-Amboseli Ecosystem (Hazzah et al., 2009; Maclennan et al., 2009).

Previous work on this compensation scheme and other aspects of its performance has been assessed and reported by Hazzah et al. (2009) and Maclennan et al. (2009). This paper chose to focus on insights obtained from the pattern of predation and the costs incurred, since in poverty stricken rural areas, costs of wildlife become crucial to both conservation and local development. The amount of money paid to community members after verification and appropriate relevant animal husbandry penalties in the two group ranches was close to KSh28 million for over 9,000 livestock killed over the duration. Since this covers just a small area of the ecosystem, considering only reported cases, this suggests a very high cost to the local communities. It also depends on significant funds to be provided by the organization, and without proper fundraising and support by government and other stakeholders in conservation, this critical program cannot be guaranteed (Nyhus et al., 2003, 2005). From discussions with communities bearing this cost, retaliation and killing of carnivore rates will be very high in the absence of such schemes, leading to concerns of carnivore extinction in the Amboseli ecosystem, raised by *National Geographic* (2008).

In a study by Hazzah et al. (2009) of the compensation scheme, the majority of the respondents had been compensated for their livestock losses, but only about half of those compensated approved of the program (Hazzah, 2006). However, a study by Kenana and Mwinzi (2010) showed that the scheme in Mbirikani had resounding successes whereby both the community and wildlife benefited through easing of economic loss, fostering positive attitudes towards wildlife and reduced carnivore mortalities. They further noted that on support structures and its operationalization platform, the compensation schemes had great successes of between 60% and 90% achievement of indicators. Program execution and administration was also very successful, as was the attainment of the objective of the MPCF. Their results further showed that whereas the success of the program has traditionally been viewed from a relatively narrow angle, as to whether there is reduction in carnivore mortalities or not, there are a number of subtle but nonetheless important successes of the scheme that enhance wildlife conservation. These successes include the reduction in hostility between community and conservationists; increased community policing on illegal activities against conservation; and positive attitudes of local community towards conservation (Kenana and Mwinzi, 2010).

This synthesis considers just a small portion of the overall cost of conservation of carnivores to the community, including just livestock death inside bomas. It does not consider injured animals or those killed during grazing, or those lost and eventually killed by carnivores. There have been many papers written to support or oppose compensation of local communities from wildlife damage (Nyhus et al., 2003, 2005; Bulte and Rondeau, 2005; Frank, 1998; Holmern et al., 2007; Maclennan et al., 2009; Hazzah et al., 2009; IUCN, 2006; Kissui, 2008; Linnell et al., 1999; Mishra et al., 2003; Montag and Patterson, 2001; Naughton-Treves et al., 2003; Wagner et al., 1997); however, without any other benefit system such as from ecotourism or private wildlife sanctuaries on their land, bearing the cost of conservation by the community without significant benefits (Ferrao and Kiss, 2000; Norton-Griffiths and Southey, 1995) and without

government and other stakeholder support is difficult on the ground (Galaty 1992). Understanding that conservation has a cost to local communities, and having government, conservationists and researchers appreciate this cost is critical to the survival of carnivores in poor countries in Africa (National Geographic, 2003; Dickson, 2005; Ginsberg et al., 1990; Hunter et al., 2007; Marker et al., 2003; Mishira. 1997; Myers, 1975). It is also important that conservationists, researchers and government take action to relieve the plight of local communities that live side by side with wildlife in order to contain the escalating negative attitudes caused by ever-increasing human-wildlife conflict (Treves and Naughton-Treves, 1999; Patterson et al., 2004; Ogada et al., 2003; Woodroffe and Frank, 2005).

Critics of compensation schemes often argue that that compensation in whatever form is neither an effective nor sustainable tool for conservation (Naughton-Treves et al., 2003). In the case of the MPCF, however, where compensation can be well below even half of livestock market value, in terms of impact and scale it is the most appreciated mitigation strategy among the Maasai, which inherently increases its sustainability. Local communities cannot be expected to appreciate the scientific and aesthetic benefits of wildlife when they are struggling with the very basics of life. Additional costs to their life and property from carnivores makes basic survival much more difficult, and violates their human right to own property and lead a peaceful life. In western countries where economic livelihoods and opportunities are greater, tolerance for wildlife in the midst of costs of conservation can be enabled. Loss of livestock, and of human life, among poor communities in Africa is a major cause for persistent negative attitudes and conflicts with wildlife, leading to widespread wildlife mortality. Compensation, when well managed and operated (such as that of Mbirikani) and when conducted alongside other benefits and awareness programs, simply helps lighten the burden, without encouraging immoral behavior, since it only pays a fraction of the total market value of the lost livestock. The change in attitudes of the Maasai and tolerance of carnivores in the Amboseli as measured by reduced retaliatory killing and a rising number of carnivores (Kenana and Mwinzi, 2010) is testament to the fact that compensation can be a highly effective conflict mitigation strategy, especially in poor rural communities in Africa.

We also see an enhanced role of adult male Maasai and morans in this respect by helping guard livestock at night. As noted by Maclennan et al. (2009), compensation should not become a source of income for the Maasai, or compensation for sick and dying livestock exposed to predation. Effective animal husbandry, establishing carnivore proof bomas, increasing home vigilance against predators at night and ensuring other forms of benefits from presence of carnivores (such as establishment of wildlife sanctuaries) and appropriately zoned land use practices should help prevent livestock predation, thereby reducing the need for compensation; these practices should be encouraged on a larger scale.

If inadequate livestock management practices were effectively rewarded through compensation payments, the impact of the compensation scheme would be reduced. Overcoming these issues is a challenge in such a support system, but can be managed well with community goodwill and good structures in place (Maclennan et al., 2009; Hazzah et al., 2009). In order to ensure that the Maasai understand that compensation is one of the last resorts to help them live side by side with wildlife, BLF also promotes prevention strategies such as employing local game scouts to reduce human-wildlife conflict and encouraging improved livestock husbandry. The verification system and penalties imposed for poor husbandry practices under MPCF ensure that Maasai are encouraged to take every action possible to prevent predation of their livestock, and perverse incentives for poor animal husbandry are limited (Maclennan et al., 2009). This is further helped by the fact that the Maasai are generally not willing to devalue their animals just for compensation, and take every measure possible to keep their livestock alive, rather than leave a sick animal out for carnivores.

Finally, since funding for compensation schemes does not flow continuously and may not always be available, we suggest that accompanying disincentives, such as rigorous law enforcement and prosecution, would help to reduce retaliatory lion-killing, also suggested by Hazzah (2006). Losses to depredation can be substantial for individuals, and some people may continue to harbor negative attitudes towards carnivores despite compensation schemes, due to general insecurity and other concerns they may have. This is also because compensation schemes cannot pay for all livestock losses in all conceivable circumstances.

Despite this, there has been a 90% decrease in the number of lions killed annually in the Amboseli ecosystem where compensation schemes exist, with numbers of lions (and of other carnivores) now increasing (Kenana, personal communication). This may be due to a combination of factors, such as the appre-ciation of the MPCF efforts; the Maasai's embrace of privately owned wildlife sanctuaries in the area; education and awareness; increased employment opportunities offered by BLF; the activities of other conservation orga-nizations operating in the ecosystem, such as African Wildlife Foundation, Lion Guardians, Amboseli Trust for Elephants, The School for Field Studies, African Conservation Centre and the Amboseli-Tsavo Game Scout Association.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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Diversity, distribution, indigenous uses and conservation prioritization of the economically important floristic diversity in Nadaun Block of Hamirpur District, Himachal Pradesh

Jyoti[1*], S. S. Samant[2], Kamal Kishor[1], Brij Mohan Upreti[1], Mamta Bharti[1], Neetu Bohra[1], Pankaj Sharma[3] and Lalit M. Tewari[1]

[1]Department of Botany, D.S.B. Campus, Kumaun University, Nainital, India.
[2]G.B. Pant Institute of Himalayan Environment and Development, Himachal Unit, Mohal- Kullu, India.
[3]Himachal Pradesh State Biodiversity Board, Himachal Pradesh State Council for Science, Technology & Environment, B-34, SDA Complex, Kasumpti, Shimla-171009, Himachal Pradesh, India.

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The present study was carried out in 11 representative villages in Nadaun Block of Hamirpur district in Himachal Pradesh. Total 265 economically important species belonging to 81 families and 211 genera includes 78 species of trees, 46 shrubs and 141 herbs were records. The dominant families were Poaceae (20 species); Fabaceae (18 species) and Asteraceae (14 species). Twenty eight (28) families were monotypic. The inhabitants use these species as medicine (210 species), wild edible/food (109 species), fodder (88 species), fuel (42 species) for religious purpose (23 species), making agricultural tools (6 species), timber (12 species) and miscellaneous (12 spp). It was found that out of 265 economically important species recorded, 26 were found to be native to the Himalayan region, 10 species native to the Himalayan region and adjacent countries and states, 243 species were non-natives. Out of the total recorded species, one species has been categorized as critically endangered, four species endemic, seven species near endemic and 14 species vulnerable.

Key words: Himalayan region, economically important, monotypic, critically endangered, vulnerable, near endemic.

INTRODUCTION

Himalaya meaning “abode of snow” is one of the largest mountain chains in the world, where floral and faunal diversity vary extensively with climate from one region to another. The Indian Himalayan Region (IHR) covering approximately 4,19,873 km^2 includes parts of Jammu and Kashmir, Himachal Pradesh, Uttrakhand (Garhwal and Kumaun), West Bengal (Darjeeling Hills), Sikkim, Arunachal Pradesh and other north eastern states. The present paper focused on diversity, distribution, indigenous uses and conservation prioritization of the economically important floristic diversity in Nadaun Block of Hamirpur district, Himachal Pradesh.

*Corresponding author. E-mail: nayan.katoch6@gmail.com. Tel: +91-7534869115.

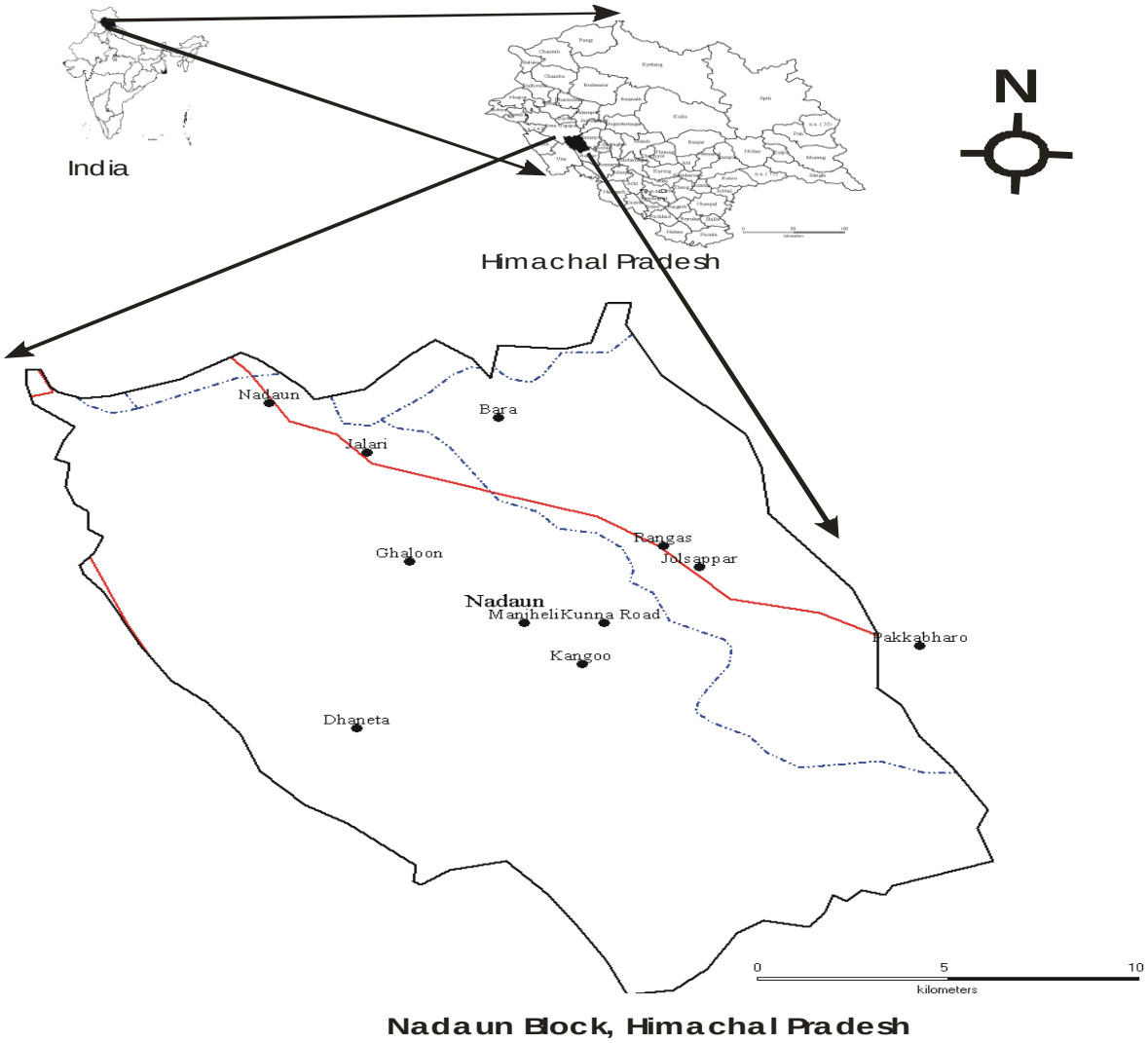

Figure 1. Map of the study area.

This region supports about 18,440 plant species, out of which 27% are endemic to the Himalaya (Samant, 1998). 1748 species of medicinal plants with various traditional and modern therapeutic uses (Samant,1998), 675 species of wild edibles (Samant and Dhar, 1997), 279 species of fodder (Samant, 1998) and 155 sacred plants (Samant and Pant, 2003) have been reported from the Indian Himalayan Region(IHR).

MATERIALS AND METHODS

Study area

The State of Himachal Pradesh (30° 22' 4" to 33° 12' 40" N latitudes and 75° 47' 55" to 79°04' 20" E longitudes) includes the parts of Trans and North Western Himalaya. Of the total area, 66.45% is under forests. Of the total forest, 20.45% area is under Protected Area Network and 3.41% area under reserve forests.

The present study was conducted in eleven representative villages: Kangoo, Dhaneta, Nadaun, Bara, Jalari, Rangas, Ghaloo, Pakkabharo, Manjhali, Jolsappa, and Kunna road. Nadaun Block is located at 31°47′N 76°21′E31.78°N 76.35°E. It is not a typical "Hilly and Chilly" type of climate in Nadaun Block as it is closer to the plains. Mainly humid sub-tropic zone occur. The mean annual temperatures vary from 20-24°C and mean annual precipitation is 1180 to 1900 mm. There has been a report of snow only once in Nadaun in 2012. Agriculture and horticulture are the amongst major livelihood options of the villages. The study area is highlighted in the Figure 1.

Eleven representative villages were selected to take information on the economically important floristic diversity and their utilization pattern by the inhabitants. Further, knowledgeable persons including village Vaidhyas from each village were interviewed. Information on the local names, altitudinal range, life forms, part(s) used, and use values including indigenous knowledge and practices were gathered.

Fresh samples of the useful species were collected and identified with the help of available literature and floras (Pangtey et al., 1991; Purohit and Samant, 1995; Samant and Pangtey, 1995; Sharma and Singh, 1996; Kala et al., 1998; Singh and Rawat, 2000; Kaur and Sharma 2004). The information was compiled and analysed for the utilization pattern following Samant, (1998).

Table 1. Taxonomic/habit wise description of economically important plants in the Nadaun Block.

Taxonomy/ habit group	Family	Genera	Species	Herbs	Shrubs	Trees
Angiosperms	80	210	264	141	46	77
Gymnosperms	1	1	1	-	-	1
Total	81	211	265	141	46	78

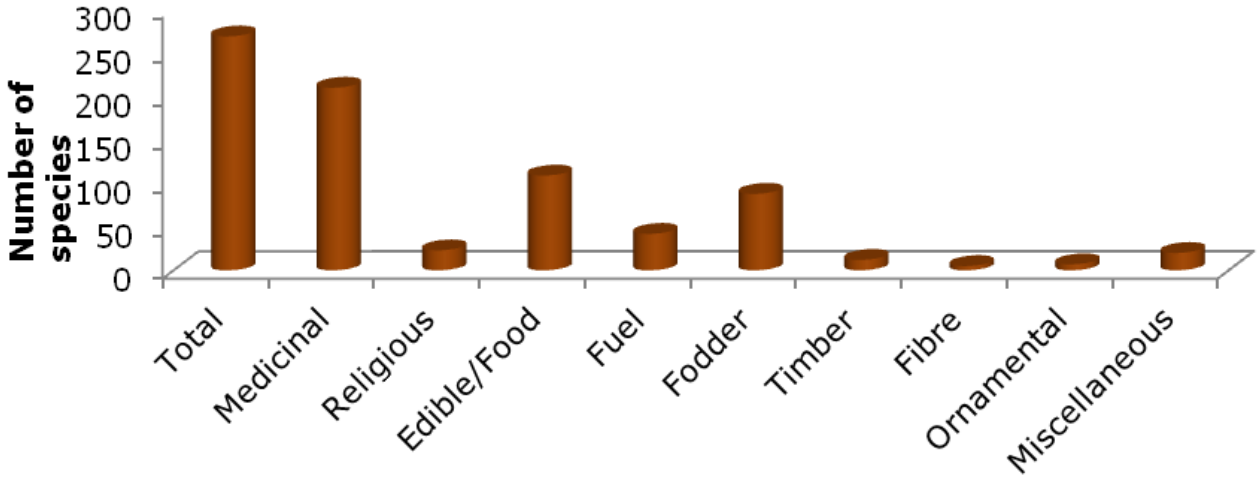

Figure 2. Utilization pattern of floristic diversity for various purposes

RESULTS

Diversity, distribution and utilization pattern

The present study records 265 economically important species belonging to 81 families and 211 genera from the Nadaun Block. Of the recorded species, 78 species were trees, 46 shrubs and 141 herbs (Table 1). The recorded species were distributed at altitude between 450-1000 masl .The dominant families were Poaceae (20 spp.); Fabaceae (18 spp.); Asteraceae (14 spp.); Lamiaceae (10 spp.); Moraceae, Caesalpiniaceae and Brassicaceae (9 spp. each); Cucurbitaceae and Apocynaceae (eight spp., each); Rutaceae and Solanaceae (seven spp., each); Euphorbiaceae and Rosaceae (six spp., each); Apiaceae and Myrtaceae (five spp., each), respectively. *Brassica* (five spp.); *Bauhinia, Terminalia* and *Citrus* (four spp., each); *Albizia, Prunus* and *Cassia* (three spp., each); *Achyranthes, Agave, Trachelospermum, Asparagus, Ageratum, Bidens, Berberis, Cucurbita, Euphorbia, Vigna, Mentha, Allium, Acacia, Morus, Syzygium, Dendrocalamus, Saccharum, Pyrus, Grewia, Viola* and *Vitis,* (two spp., each) were the dominant genera. Twenty eight families were monotypic. The inhabitant of Nadaun Block use these species as medicine (210 spp.), wild edible/food (109 spp.), fodder (88 spp.), fuel (42 spp.), for religious purpose (23 spp.), making agricultural tools (6 spp.), for timber/house building (12 spp.), and for other purposes (12 spp.) (Figure 2).

The notable medicinal plants were *Adhatoda vasica, Acorus calamus, Achyranthus aspera, Centella asiatica, Spilanthes oleracea*, *Terminalia arjuna*, *T. chebula*, *Cuscuta refle, Ajuga parviflora*, *Mentha longifolia*, *Aloe barbadensis*, *Azadirachta indica*, *Melia azedaracht*, *Tinospora cordifolia, Acacia catechu*, *Murraya paniculata, Bacopa monnieri,* etc.; wild edibles were *Carissa opaca, Phoenix humilis, Cordia dichotoma, Tamarindus indica*, *Acacia nilotica, Morus alba*, *Psidium guajava*, *Syzygium cumini*, *Ziziphus mauritiana*, *Ficus palmata*, *Pyrus pashia*, etc.; fodder were *Deeringia amaranthoides*, *Asparagus adscendens*, *Brassica campestris*, *Stellaria media*, *Terminalia myriocarpa*, *Shorea robusta*, *Mallotus philippensis*, *Trifolium repens*, *Linum usitatissimum*, *Toona ciliata*, *Albizia lebbeck*, *Dendrocalamus strictus*, *Grewia asiatica*, etc.; those used as fuel were *Mallotus philippensis*, *Diospyros Montana*, *Pinus roxburghii*, *Bauhinia retusa*, *Terminalia myriocarpia*, *Toona ciliate* etc.; timber were *Bombax ceiba*, *Cordia dichotoma*, *Terminalia myriocarpa*, *Dalbergia sissoo*, *Juglans regia*, *Toona ciliata*, *Albizia lebback*, *Syzygium cumini*, *Pinus roxburghii* etc.; and plants for religious purpose were

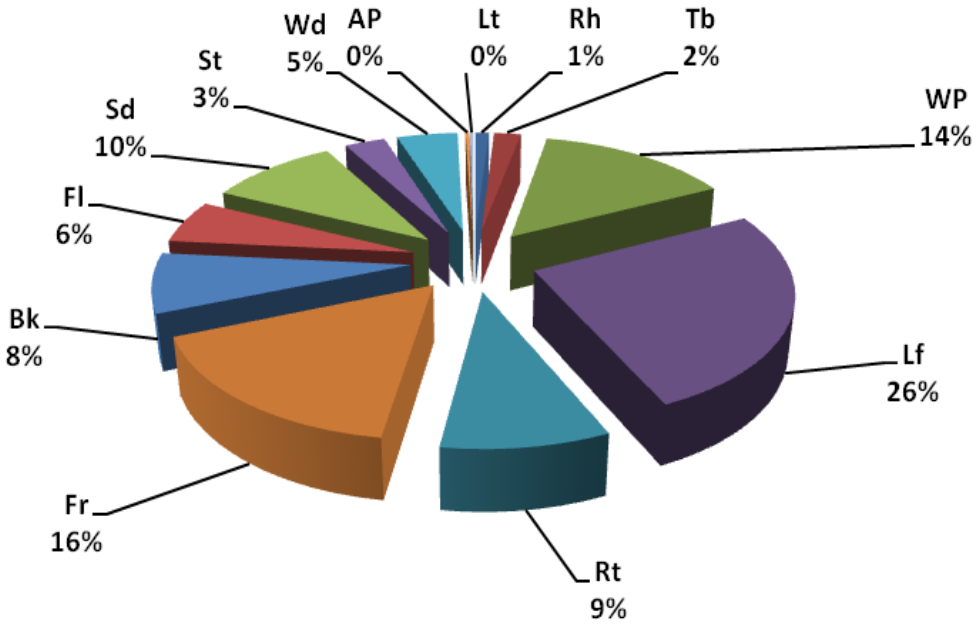

Figure 3. Statistics of plant parts used. Fr = Fruit; Rt = Root; Lf = Leaf; WP = Whole Plant; Bk = Bark; Fl = Flower; Sd = Seed; Tb = Tuber; Rh = Rhizome; St = Stem; Lt = Latex; Wd = Wood and AP = Aerial Parts.

Bauhinia variegata, *Ficus bengalensis*, *Centella asiatica*, *Evolvulus alsinoides*, *Ocimum sanctum*, *T. cordifolia*, *Cynodon dactylon*, *Ficus religiosa*, *Valeriana jatamansi*, etc. The different parts these of plant are used for caring different diseases and economic uses (Figure 3).

Indigenous uses

Out of the 265 economically important species, 210 species were used for curing various diseases/ailments. For example, leaves of *Amaranthus hybridus* is used in diarrohea, dysentery and eczema; shoots of *Adhatoda vasica* is used in for cold, cough, bronchitis, early asthma, fever, sedative and as antiseptic; *Phoenix humilis* is used in sprain; roots of *Hedychium spicatum* is used for the treatment of asthma, bronchitis, eye problems, gastric dysfunction, as tonic and blood purifier; roots and leave of *Strobilanthes atropurpureus* is used as antidote for snake bite, bronchitis, pneumonia, wounds, headache and swelling; root of *Rauvolfia serpentina* is used widely applied in the case of intestinal disorders, in opacity of cornea, in the case of high fever, nervous disorders and in cholera; flower of *S. oleracea* is used in toothache, in throat problem, used as a stimulant and as diuretic. The remaining species were used for the treatment of various diseases/ailment (Appendix 1).

DISCUSSION

Plant resources are used by mankind to meet their daily needs. Man has been using plants as medicine, food (edible), fuel, fodder, timber, agricultural tools, for religious purpose and other purposes since time immemorial (Samant et al., 1996; Samant and Dhar, 1997). In spite of the efforts made by various workers, the information still remains fragmentary and most of the biodiversity rich areas remained unexplored or under explored (Samant, 1998).

Multipurpose utility of *B. ceiba, Cannabis sativa, Terminalia chebula, Terminalia bellrica, Emblica officinalis, Dalbergia sissoo, Pinus roxburghii, Juglans regia*, *Melia azedaracht*, *Reinwardtia indica*, *Acacia catechu*, *Aegle marmelos* and *Pistacia integerrima* indicated high pressure on these species. These species are facing high anthropogenic pressures in the area due to habitat degradation and over exploitation of propagating parts mainly roots/tubers/rhizomes of *Aconitum heterophyllum*, *Acorus calamus*, *Rauvolfia serpentina*, *Hedychium spicatum*, *Gloriosa superb*, etc, and fruits and seeds of some of the species which may lead to extinction of these species in near future.

The over exploitation and habitat degradation of some of the high value species have caused severe threat to these species. Such continued practices will cause the loss of these species and also, loss of moisture and humus content which will lead soil erosion and finally habitat degradation. It has been observed that due to unplanned collection of the resources, ecology of the forests has been seriously affected. Similar problems are also prevalent in the Nadaun Block. Therefore, adequate conservation measures have to be taken to maintain current status of the habitats, species and communities

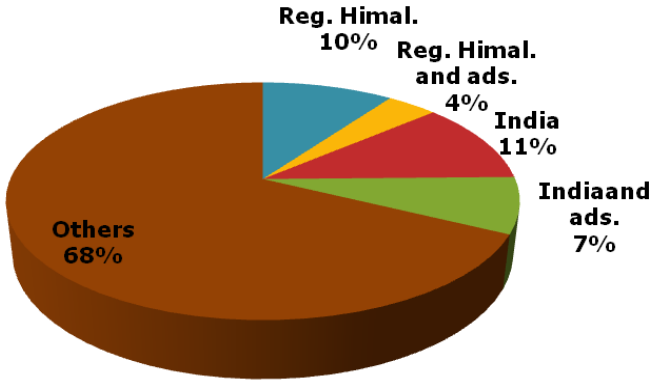

Figure 4. Native and non-native species of Nadaun Block.

and for the effective management of the economically important plants of Nadaun block. Awareness among the inhabitants of the Nadaun Block needs to be created for the resource utilization techniques, so that sustainable utilization of the species could be done by the inhabitants.

Analysis of nativity and endemism of floristic diversity

Native and endemic species play an important role in assessing the conservation value of any habitat, community and ecosystem, for making a strategy and action plan for conservation and management of a particular biogeographic province, state, district, tehsil, block, watershed, valleys and catchments

Out of the total 265 economically important species recorded from the Nadaun Block, 26 species (10%) were native to the Himalayan region, 10 species (4%) native to the Himalayan region and adjacent countries and states, 29 species (11%) were recorded from India, 19 species (7%) from India and adjacent countries, whereas 181 species (68%) were non-native representing other biogeographical regions such as Arabia, Australia, America, Africa, Japan, Malaysia, etc. (Figure 4).

The depleting population of native and endemic species and invasion by non-natives is a great concern due to the negative impacts of non-natives on the other species of a particular region and even entire ecosystems. The past studies have proved that non-natives affect the hydrology and nutrient cycles of entire ecosystems .Such impact leads to the extinctions of the native and endemic species.

Rarity and prioritization of species for conservation and management

Diversity and distribution pattern of threatened plants

The economically important floristic diversity has been analyzed for rarity. Of the total recorded species, 1 species have been categorized as critically endangered (*Rauvolfia serpentina*), four endangered (*Dioscorea deltoidea*, *Shorea robusta*, *Gloriosa superba* and *Withania somnifera*) and 14 vulnerable (*Acorus calamus*, *Pistacia integerrima*, *Asparagus recemosus*, *Berberis aristata, Berberis lycium*, *Capparis zeylanica*, *Terminalia arjuna*, *Costus specious*, *Cinnamomum tamala*, *Azadirachta indica*, *Thalictrum foliolosum*, *Aegle marmelos*, *Zanthoxylum armatum* and *Hedychium spicatum*). There are other species facing habitat degradation and over exploitation and may be considered to be under near threatened and least concern categories.

Studies have been conducted to explore and identify the threatened plants including medicinal plants of the Indian Himalayan Region by some workers (Badola and Pal, 2003). However, in most of the studies, identification of threatened species has been carried out using qualitative attributes/observations, only. Assessment of status of the species using qualitative as well as quantitative attributes has been suggested by few workers (Samant, 1998).

Habitat degradation and overexploitation were the two major factors responsible for the population depletion of the economically important species. Most of the species were severely affected by both factors.

Further promotion of mass scale propagation through conventional and *in vitro* methods of such species and their rehabilitation in the *in situ* conditions or similar habitats may also help in conservation and management. The developed seedlings need to be disseminated among the farmers for mass scale plantation/cultivation. All the species categorized under various categories of rarity are traded, hence prioritized for conservation.

Conflict of Interest

The author(s) have not declared any conflict of interest.

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Appendix 1. Diversity, distribution, indigenous uses and conservation prioritization of the economically important floristic diversity in Nadaun Block of Hamirpur District, Himachal Pradesh.

Family/Taxa	Local Name	Altitudinal Range (m)	Life form	Part/s Used	Nativity	Indigenous uses
Acanthaceae						
Adhatoda vasica Nees	Basuti	500-900	Sh	WP	As Trop	Medicinal (cold, cough, bronchitis, early asthma, fever, sedative, expectorant, antispasmodic, rheumatism and antiseptic); miscellaneous (dye)
Dicliptera roxburghiana Nees	-	550-1000	H	WP	Ind Or	Medicinal (tonic)
Peristrophe bicalyculata Nees	-	400-600	H	WP	As et Afr Trop	Medicinal (eye disorder, fracture and sprain)
Rungia pectinata (L.) Nees	-	600-900	H	WP	Ind Or Burma	Medicinal (small pox and urine complications); Edible
Acoraceae						
Acorus calamus L.**	Bare/ Bauch	800-1000	H	WP	Reg Bor Temp	Medicinal (Bitter tonic, carminative, emetic, antispasmodic, dyspepsia, diarrohea, nerviness tonic, fevers and bronchitis)
Achyranthaceae						
Achyranthes aspera L.	Puth kanda	450-1000	H	WP	Trop	Medicinal (asthma, bronchitis, cold, cough, dysentery, germicide, headache, laxative, leucoderma, piles, pneumonia, rheumatism, skin diseases, sore, stomach, tonic, whooping cough, wounds and veterinary diseases); Religious
A. bidentata Bl.	-	500-950	H	WP	As Trop	Medicinal (blisters in mouth, cholera, scorpion sting, swelling, whooping cough)
Alliaceae						
Allium cepa L.	Pyaz	500-1000	H	WP	Asia Temp	Medicinal; edible
Allium sativum L.	Lahsun	500-1000	H	WP	Europe	Medicinal (rheumatic pain, chronic ulcers, antibiotic activity, neuralgic pain and leprosy); miscellaneous (ropes)
Amaranthaceae						
Amaranthus hybridus L.**	Bathu	550-1000	H	Lf, Rt	Am Bor	Medicinal (diarrohea, dysentery, colic and eczema); edible
Deeringia amaranthoides (Lam.) Merr.**	-	600-1000	H	Lf, Fr	Reg Himal China	Medicinal (Sores); Fodder
Agavaceae						
Agave angustifolia Haw.	Rambaan	600-1000	H	Lf	As Trop	Miscellaneous (ropes); piscicidal
A. cantula Roxb.	-	450-900	H	Lf, Rt	As Trop	Miscellaneous (ropes); piscicidal
Anacardiaceae						
Lannea coromandelica (Houtt.) Merr.	Salam bada	500-900	T	Bk, Lf	As et Afr Trop	Medicinal (astringent, bruises, skin eruptions, heart diseases, dysentery, mouth sores, toothache, local swelling and pains)
Mangifera indica L.	Aam	700-750	T	WP	Ind Or Malaya	Medicinal (laxative, diuretic, stomach debility, uterine hemorrhage, skin diseases, nasal bleeding, melanin, Antifertility, cancer, dropsy, digestion, eye complaints, fever, rheumatism, laxative, jaundice, diarrhoea and anasarca); edible; religious
Pistacia integerrima Bin. Stewart **	Kakarsingh	600-1000	T	Fr	Egypt Persia, Reg Himal	Medicinal (tonic, expectorant, cough, asthma, fever, appetite, chronic pulmonary affection, dysentery, vomiting, diarrhoea); edible; fodder; fodder; timber; miscellaneous (dye)

Appendix 1. Contd.

Apiaceae						
Centella asiatica L.	Brahmi	700-1000	H	Rt Fl	Reg Trop et Sub	Medicinal (Nerving, cardio-tonic, improves memory, dermatitis, cough, diabetes, anemia, insanity, eye troubles, skin diseases, leprosy, blood diseases and antiseptic); Religious
Coriandrum sativum L.	Dhania	450-1000	H	WP	Europe, Austr	Medicinal (Stimulant, carminative, diuretic, tonic, and stomachic); Edible
Daucus carota L.	Gajar	450-1000	H	Tb	Europe Austr	Medicinal (Heart problems); Edible
Foeniculum vulgare Mill.	Saunf	450-1000	H	WP	Europe Austr	Medicinal (Carminative, vermicide, colic pain and diuretic); Edible
Trachyspermum ammi L.	Ajowain	450-1000	H	WP	Europe Ind	Medicinal (Tonic, diarrhea, atonics dyspepsia, colic, flatulence, cholera, diuretic, antiseptic and carminative); Edible
Apocynaceae						
Carissa opaca Stapf ex Haines	Garnoin	500-1000	Sh	Lf Fr	Ins Moluce	Medicinal (Appetizer); Fodder; Edible; Fuel
Holarrhena pubescens Wall. and G. Don	-	700-800	Sh	WP	Ind Or	Medicinal (Antidote to snake bite, bronchial fever, diarrhea, malaria)
Nerium indicum Miller	-	500-900	Sh	Lf, Rt	Cosmop	Medicinal; Ornamental
Rauvolfia serpentina Benth. ***	Sarapgandha	600-1000	Rt	Rt	Trop Himal Ind Malaya	Medicinal (Fever, nervous disorder, insomnia, intestinal disorders, cholera, colic, opacity of cornea, reserpine in fevers); Fodder
Trachelospermum fragranus Hk.f.	-	850-950	Sh	Fr	Reg Himal	Medicinal (Tonic, convalescence, constitutional debility)
T. lucidum (Don) Schum.	-	800-900	Sh	WP	Reg Himal	Medicinal (Boils, eye problem, fever, headache)
*Vallaris solanacea (*Roth) Ktze.	-	500-1000	Sh	St, La,	Ind Or Burma	Medicinal (Abortificant. Wounds); Fiber; Miscellaneous (Household)
Vinca rosea L.	Sadabahar	800-1000	H	WP	Cosmop Trop	Medicinal (Cold, cough)
Araceae						
Colocasia esculenta Schott	Arvi/Kachalu	600-1000	H	LF Tb	Trop	Medicinal (Decoction, heart disease Edibles)
Arecaceae						
Phoenix humilis Royle	Khajoor	600-800	T	Rt, Lf, Fr	Ind Or Burma	Medicinal (Sprain); Edible; Miscellaneous (broom); Fiber
Asclepiadaceae						
Calotropis procera (Dryand.) Aiton	Ak	500-1000	H	Fr, Lf	Peru Afr Trop	Medicinal (Dysentery, diaphoretic, expectorant, fevers, cough, cold and asthma); Miscellaneous (Fiber)
Cryptolepis buchananii Roem. and Schultes	-	900-1000	Sh	WP	Ind Or	Medicinal (Rickets); Fiber
Asparagaceae						
Asparagus adscendens Rox.	Safed musli	500-1000	Sh	Lf, Fr	Reg Himal	Edible; Fodder; Medicinal
A. racemosus Wild.**	Sanserpali	500-1000	Sh	Fr	Ind Afr Austr Trop	Medicinal (Antifertility, asthma, burns, child birth, hydrophobia, ringworm, snakebite, spleen complaints and toothache)

Appendix 1. Contd

Asteraceae						
Ageratum conyzoides L.	Ookalbuti	500-1000	H	Lf, Rt, Sd, Fl	Reg Trop	Medicinal (Antilithic,antiseptic, burns, cancer, cuts, diarrohea, headache,snake bite, ring worn, sores, uterine disorders and hair problems); Edible
A. houstonianum Mill.	Chhota phulnu	750-900	H	Lf	Am Bor	Medicinal (Anti-inflammatory, antibacterial, antifungal)
Argemone mexicana L.	-	500-1000	H	Rt, Lf Sd	Reg Trop	Medicinal (Malaria, leprosy, skin diseases, inflammations, purgative, sedative, ophthalmia, rheumatism, tumer, anthelmintic)
*Bidens biternata (*Lour.) Merr. and Sherff.	-	500-1000	H	Fr, Lf, Fl, Rt	Reg Trop	Medicinal (Appetizer, cough, cuts, inflammation, snake bite)
B. pilosa L.	Lumb	500-900	H	Lf, Fl	Ind Occ Am austr	Medicinal (Cough, antiseptic, foul, ulcers, swollen glands, eye problems and ear trouble)
Conyza stricta Wild.	-	500-1000	H	Lf, Fl	Ind Or Afr Trop	Fodder; Aromatic
Galinsoga ciliata Ref.	Banmara	900-1000	H	Lf, Fr	Mexico Am	Fodder; Edible
Helianthus annus L.	Surajmukhi	500-900	Sh	Sd, Fr,Rt	Am Bor	Medicinal (Bronchitis, fever, diuretic, pulmonary infections and astringent); Edible; Fodder; Fuel; Miscellaneous (Paper)
Sonchus asper L. Hill.	-	500-1000	H	Lf, Rt,	Cosmop	Medicinal (Cough, bronchitis, asthma and eye trouble); Edible; Fodder
Spilanthes oleracea L.	Akkarkarha	450-900	H	Fl	South America	Medicinal (Toothache, throat,gum infection, inflammation, stimulant, scurvy, dysentery, as diuretic and mosquito repellent)
Stevia rebaudiana Hemsl.	Stevia	600-900	H	Lf,Fl	Parag	Medicinal (Control diabetes)
Tagetes erecta L.	Genda	700-1000	H	Fl, Lf	Am Trop	Ornamental
Taraxacum officinale Weber. ex. Wiggers	Kanphul	700-1000	H	WP	Reg Temp Bor et	Medicinal (Laxative, diuretic, hepatic stimulant, stomachic, vermifuge, dropsy and drug); Edible
Tridex procumbens L.	-	900-1000	H	WP	Am Trop	Medicinal (Antiseptic, pimples, anemia, antifertility, aphrodisiac, boils, bone fracture, chicken pox, cholera, cough, diarrohea, fever, skin diseases, leprosy, tonic, urine complaint)
Berberidaceae						
Berberis aristata Dc.**	Kshambal	900-1000	Sh	Rt,Sd, WP	Reg Himal	Medicinal (Snake bite, boil, eye complaints); Fodder
B. lycium Royle**	Kasmal	500-900	Sh	WP	Reg Himal	Medicinal (Dysentery, diarrhea, skin disorders); Fodder
Bombacaceae						
Bombax ceiba L.	Simbal	900-1000	T	Rt,Bk,Lf	Amer Austr	Medicinal (Stimulant, tonic, emetic, dysentery and diarrhea); Edibles; Fiber; Timber; Agricultural tools
Brassicaceae						
Brassica campestris L.	Toria	450-1000	H	Lf,Sd	Cosmop Europe	Medicinal; Feed; Edible
B. nigra Koch	Rai	450-1000	H	Sd	Cosmop Europe	Medicinal; Fodder
B. oleracea L. var. *oleracea*	Phulgobbi	450-1000	H	Fr, Sd	Cosmop Europe	Edible
B. oleracea L. var. *capitata*	Bandgobba	450-1000	H	Fr, Lf, Sd	Cosmop Europe	Edible
B. rapa L.	Shalgum	450-1000	H	Tb, Lf	Cosmop Europe	Edible
Eruca sativa Mill.	Taramira	450-1000	H	Lf, Sd	Reg Mediter	Fodder

Appendix 1. Contd.

Raphanus sativus L.	Mooli	450-1000	H	Rt	Europe	Medicinal; Feed; Edible
Sisymbrium sophia L.	Jangli saron	500-1000	H	Lf, Fl	Europe	Medicinal (Ulcers); Fodder
Lepidium sativum L.	Halim	500-1000	H	Lf	Reg Temp	Medicinal (Asthma, cough, heart trouble, laxative, insomnia, diuretic and liver diseases); Edible; Fodder
Buddlejaceae						
Buddleja asiatica Lour.	Bana	600-1000	Sh	Lf	As Trop Malaya	Medicinal (Inflammation, skin diseases, abortive); Edible
Cactaceae						
Cactus monacantha Haw.	Naag-phani	600-1000	Sh	WP	Am Austr	Medicinal (Nutritious, cough)
Caesalpiniaceae						
Bauhinia racemosa Lamk.	-	600-900	T	Lf, Bk	Ind Or Burma China	Medicinal (Diarrhoea, dysentery); Edible; Fuel; Fodder; Miscellaneous (Household)
B. retusa Roxb.	-	700-1000	T	Bd, Fl	Reg Himal	Medicinal (Cholera, snake bite); Fuel; Fodder
B. vahlii (WtandArn.) Benth.	Tour	500-1000	Sh	Sd	Ind Or	Medicinal (Antifertility, dysentery, fatness, stomachache, tonic); Edible; Household; Fuel; Fodder; Religious
B. variegata L.	Krailaya	700-1000	T	Lf, Bk, Fr, Fl	Ind Or Burma China	Medicinal (Diarrhoea, dysentery, fatness, factual, piles, scrofula, skin diseases, leprosy, snake bite, tumors, ulcers and worms); Fodder; Fuel; Edible; Religious
Caesalpinia bonduc L. Roxb.	-	700-900	Sh	Rt, Bk, Sd	Cosmop Trop	Medicinal (Anthelmintic, stomachic, diuretic, anti-pyretic, febrifuge expectorant)
Cassia fistula L.	Amaltas	500-1000	T	Rt,Lf,Fr ,Bk	As Trop	Medicinal (Constipation, cold, fever, liver disorder, tuberculosis glands, haematemesis, typhoid, asthma and leprosy)
C. occidentalis L.	-	500-1000	Sh	Rt, Lf,	Cosmop Trop	Medicinal (Diuretic, fevers, asthma, bronchitis, menstrual problems, tuberculosis, anemia, liver complaints, general weakness, gonorrhea, urinary tract disorders, stomach cholic, anti-inflammatory, skin disorders)
C. tora L.	-	700-1000	H	Sd, Lf	Cosmop Trop	Medicinal (Antispasmodic, carminative, emollient, purgative, indigestion, skin diseases)
Tamarindus indica L.	Imli	4500-900	T	Fr,Bk	Ind Or	Medicinal (Wounds, asthma); Edible; Fodder; Fuel; Cosmetic; Agricultural tools
Cannabaceae						
Cannabis sativa L.	Bhang	500-1000	H	St,Sd	As Centr	Medicinal (Tonic, intoxicant, antiseptic, analgesic, sedative and narcotic); Religious
Capparaceae						
Capparis zeylanica L.**	-	600-800	Sh	WP	Ind Or	Medicinal (Ant helminthes, blisters, boils, cholera, colic, pneumonia, piles, rheumatism, snake-bite, swell testicle, ulcers); Edible
Carcicaceae						
Carica papaya L.	Papita	450-1000	T	Fr, Sd, St	Ind Or	Medicinal (Stomachic, carminative, diuretic, anthelmintic and sedative tonic); Miscellaneous (Ropes); Edible; Religious
Caryophyllaceae						
Stellaria media L.Vill.	Khokhua	500-1000	H	Lf, Fl	Reg Temp	Medicinal (Intestinal problems, renal, respiratory,inflammations, erysipelas, burns); Edible; Fodder
Chenopodiaceae						
Chenopodium album L.	Bathua	450-1000	H	Lf	Cosmop	Medicinal (Spleen disorders); Edible; Fodder

Appendix 1. Contd.

Spinacia oleracea L.	Palak	450-1000	H	WP	Cosmop	Medicinal (antibacterial, demulcent, diuretic, fever and intestinal inflammations); edible
Combretaceae						
Terminalia arjuna (Roxb.) Wt. andArn.	Arjun	700-1000	T	Bk,Fr,Sd	Ind	Medicinal (tonic, febrifuges, ant dysenteric, cardio tonic and diuretic); timber; ornamental; fodder; fuel
*T. bellirica (*Gaertn.) Roxb.	Bahera	500-1000	T	Fr,St	Ind Or Malaya	Medicinal (antipyretic, diarrhea, bitter astringent, dyspepsia, tonic, stimulant, diuretic, carminative and antispasmodic); Fodder; fuel; agricultural tools
T. chebula Retz.	Harad	700-1000	T	Fr,Bk,Sd	As Trop	Medicinal (chronic ulcers, gargle instomatitis, bleeding gums, bark diuretic, in asthma, triphala); fuel
T. myriocarpa Heurck. and Muel.-Arg.	Alsan	500-1000	T	WP	As Trop	Fodder; fuel; timber
Commelinaceae						
Commelina benghalensis L.	-	500-800	H	Lf, Rt	Geront Trop	Medicinal (ache, dysentery, fever, scorpion bite, wounds); Edible
Cyanotis cristata (L.) D. Don	-	500-1000	H	Lf	Ind Or Malaya	Medicinal (sores); fodder; edible
Convolvulaceae						
Convolvulus arvensis L.	-	600-1000	H	WP	Geront Trop	Medicinal (purgative, burns, bruises); miscellaneous (detergent)
Evolvulus alsinoides (L.)	-	800-1000	H	WP	Amphig Trop	medicinal (asthma, fever, scorpion sting, stomachace); Religious
Cordiaceae						
Cordia dichotoma L.	Lasora	800-1000	T	Fr, Bk	Ind Or	Medicinal (astringent, anthelmintic, diuretic, lung and spleen trouble, antiseptic, kernels in ringworm injection and decoction in fever); edible; timber; fuel
Cuscutaceae						
Cuscuta reflexa Rox.	Akashbel	800-1000	H	Rt, Lf	Ind	Medicinal (Hepatic, laxative, carminative,urinary,spleen, liver disorders and pain relieving); ornamental
Costaceae						
Costus specious Sm.**	-	500-900	H	Fl	Ind Or Malaya	Medicinal (astringent, anthelmintic, snake bite, depurative and purgative); edible
Crassulaceae						
Kalanchoe spathulata DC.	-	700-1000	H	Lf	As Trop	Medicinal (healing for scar)
Cucurbitaceae						
Benincasa hispisa L.	Petha	450-1000	H	Fr	Cosmop	Edible (vegetable)
Coccinia grandis (L.) Voigt	-	900-1000	H	WP	Ind Or	Medicinal (cold, cough, diabetes, headache, filarial, swell, slow pulse, sores, syphilis, throat effect, vomit)
Cucumis sativus L.	Khira	450-1000	H	Fr	Trop	Edible
Cucurbita maxima Dch.	Kaddu	450-1000	H	Fr	Ind	Edible (vegetable)
C. pepo L.	Pumpkin	450-1000	H	Fr	Cosmop	Edible (vegetable)
Luffa cylindrica M. Roem.	Tori	450-1000	H	Fr	China Ind	Edible
L.acutangula M. Roem	Kali tori	450-1000	H	Fr	Trop Geront	Edible
Momordia charantia L.	Karela	450-1000	H	Fr	Ind Cosmop	Edible; medicinal

Appendix 1. Contd.

Cupressaceae						
Thuja orientalis L.	Saruwa	450-1000	H	Twg	China Japan	Medicinal (rheumatism, astringent, coughs, scurvy, diuretic, uterine stimulant and emmenagouge); ornamental
Cyperaceae						
Cyperus compressus L.	-	800-1000	H	WP	Cosmop Trop	Fodder
*Fimbristylis dichotoma (*Vahl) Kunth	-	700-1000	H	WP	Ind Or Madag Ins Philipp	Fodder
Dioscoreaceae						
Dioscorea bulbifera L.	-	600-1000	H	Tb	As Trop	Medicinal (abdominal pain, boils, bone fracture, dysentery, piles, jaundice); edible
D. deltoidea Wall.ex Kunth*	Shingli-mingli	800-1000	H	Tb	Ind Or	Medicinal (Dysentery, piles); Edible
Dipterocarpaceae						
Shorea robusta L.*	Sal	450-1000	T	Lf,Wd Bk	Ind	Medicinal (yield honey, dysentery, gonorhoea, and aphrodisiac); timber; fodder; resin
Ehretiaceae						
Ehretia acuminata R.Br.	-	700-900	T	Bk, Fr, Wd	As et Austr Trop	Medicinal; (Sores on tongue); Edible; Agricultural tools
E. laevis Roxb.	-	500-700	T	Lf, Bk, Fr	As et Austr Trop	Medicinal (Muscle pain); Edible
Ebenaceae						
Diospyros montana Roxb.	-	500-1000	T	Wd	As Trop	Fuel; agricultural tools; fodder
Euphorbiaceae						
Emblica officinalis L.	Amla	500-1000	T	Fr, Lf, Bk	Ind	Medicinal (acrid, cooling, anemia, eye disease, cough, heart disease); fodder; fuel; miscellaneous (tannin)
Euphorbia hirta L.	Dhudni	500-1000	H	WP	Amphig Trop	Medicinal (Antidote, snake bite, kidney disease, pain in joints, veterinary diseases, bone fracture); Edible
E. royleana Boiss.	Chhoein	800-1000	Sh	WP	Reg Himal	Medicinal (Stop bleeding, burns, ear complaints, skin disorders and wounds)
Mallotus philippensis Muell. - Arg	Kamal	600-1000	T	Sd, Fr	As et Austr Trop	Medicinal (Blisters, boils, skin diseases, snake bite); Fuel; Miscellaneous (Dye)
Ricinus communis L.	Arandi	500-1000	Sh	Fr	Reg Trop	Medicinal(Laxative, sores); Edible
*Sapium insigne (*Royle) Benth.	-	500-700	T	La	Ind Or	Medicinal (Germicide)
Fabaceae						
Abrus precatorius L. Benth.	Ratti	500-1000	Sh	WP	Reg Trop	Medicinal (Body pain, inflammation, promotes constipation); Religious
Arachis hypogea L.	Mungphali	600-800	H	Sd	As Trop	Edible; Fodder
Butea monosperma L.	Palash,Dhak	600-1000	T	Sd,Fl	Ind Or burma	Medicinal (Anthelmintic, gum, astringent, tonic, snake bite, antiseptic); Fodder; Edible; Fuel
Cicer arietinum L.	Channa	500-900	H	WP	Europe Ind	Medicinal (Jaundice); Edible
Dalbergia sissoo Roxb.	Shisham	500-700	T	WP	Ind Or Afghan	Medicinal (Decoction in gonorrhea, astringent, leprosy and skin diseases); Timber; Fodder
Erythrina suberosa Roxb.	-	600-700	T	Bk	Ind Or	Medicinal (Dysentery)
Glycine max Merr.	Soyabean		H	Sd,Fr	As Trop	Medicinal (Veterinary diseases); Edible
Indigofera atropurpurea Buch. Ham. ex Horn.	Kathi	700-1000	Sh	Lf, Wd	Reg Himal China	Fuel; Fodder; Miscellaneous (Dye)

Appendix 1. Contd.

Lathyrus aphaca L.	Mithi matar	900-1000	H	Sd	Reg Himal	Fodder; edible
Lens esculenta Medik.	Masur		H	Sd	Ind	Edible
Millettia auriculata (Benth.) Baker	-	500-800	Sh	WP	Reg Himal	Medicinal (kill lice and ticks, spleen dislocation, toothache, kill bed bugs, fever); fodder
Mucuna pruriens (L.) DC.	Darygal	500-800	H	WP	Amphing Trop	Medicinal (Anasarca, aphrodisiac, appetizer, ulcers, bone fracture, cancer, cough, cold, dropsy, dysentery, diarrohea, eye disorders, snake bite and madness)
Ougeinia oojeinensis (Roxb.) Hochr.	-	500-1000	T	St, Lf	Ind Or	Medicinal (asthma, cholera, dysentery); edible; fuel; fodder, agricultural tools.
Phaseolus vulgaris L.	French beans	450-1000	H	Sd	Cult	Medicinal (diuretic, kidney ailments, emollient); edible; fodder
Pisum sativum L.	Matar	450-1000	H	WP	Cult	Edible; fodder
Trifolium repens L.	Barseem	500-1000	H	WP	Geront Temp	Medicinal (detergent, depurative, tincture as ointment, astringent); fodder
Vigna mungo (L.) Hepper	Urd/Mah	450-1000	H	Sd	Ind Or As Trop	Edible
V. radiata (L.) Wilc.	Moong	450-1000	H	Sd	Reg Trop	Edible; fodder
Flacourtiaceae						
Xylosma longifolum Clos.	-	700-1000	T	Fr, Sd	Reg Himal	Medicinal (Stomachache); Fuel
Juglandaceae		700-1000	T	Bk, Lf	Reg Himal	
Juglans regia L.****	Akhrot	500-1000	T	Sd,Fr	Reg Himal	Medicinal (Tonic, stomachic, gastric acidity, antiseptic, tooth power, mouth wash, herpes, rheumatism); Fodder; Timber
Lamiaceae						
Ajuga parviflora Wall. ex.Benth.	Neel kanthi	700-1000	Sh	Lf	Afr Trop Ind Or As	Medicinal (gout and rheumatism)
Colebrookia oppositifolia	Gadush	600-1000		Lf,St	Ind Burma	Medicinal (burns, cold, cough, cuts, toothache)
Mentha longifolia L.	Pudina	700-1000	H	Lf	Ind Or, Europe	Medicinal (carminative, antiseptic, stimulant, rheumatic pain, fevers, heat apoplexy, cough and cold); edible
M. piperata L.	Vicks plant	500-1000	H	Lf		Medicinal (cold, cough, fever)
Ocimum gratissimum L.	Tuksi	450-1000	H	Lf	Ind	Medicinal (antibacterial, insecticidal property, fever, cold, cough); Religious
O. sanctum L.	Tulsi	450-1000	H	Lf	Europe, Afr Trop	Medicinal (antibacterial, insecticidal property, fever, cold, cough); religious
Origanum vulgare L.	Bantulsi	700-1000	H	WP	European As et Afr Bor	Medicinal (tonic, stimulant, rheumatism, diaphoretic, diuretic, whooping cough and bronchitis); cosmetic; edible
Lavandula angustifolia Mill.	Lavander	600-700	H	Lf		Medicinal (insect repellant); cosmetic
Pogostemone bengalensis (Burma. f. Ktze.	-	500-900	H	Lf	Ind Or	Medicinal (cuts, fever)
Scutellaria angulosa Colebr.	-	700-900	H	Lf	Reg Himal	Medicinal (dysentery, vomiting)
Lauraceae						
Cinnamomum tamla Nees**	Meethipatta	500-1000	T	Lf.Bk	Reg Himal	Medicinal (sedative, antiseptic, diaphoretic, anthelmintic, stimulant, carminative, toothache, muscular strain, diarrhoea and joint pains); Religious
Leeaceae						
Leea aspera Edgew.	-	900-1000	H	RT	Ind Or	Medicinal (skin diseases and ring worm); fodder; edible

Appendix 1. Contd

Liliaceae						
Aloe barbadensis Mill.	Alovera	600-900	H	Lf	Reg, Meditr	Medicinal (Stomachic, anthelmintic, piles, cathartic, colic pain); Cosmetic
Gloriosa superba L.*	-	600-700	H	Lf, Rt, Rh,Tb	Trop Afr	Medicinal (Pimples, skin irruptions, snake bites, curing baldness, bruises, chronic ulcers, hemorrhoids, cancer, leoprsay, skin infections, laxative, piles, inflammation, abdominal pains, intestinal worms, infertility and skin problems)
Linaceae						
Linum usitatissimum L.	Alsi	600-1000	H		Europe, orient	Medicinal (Skin infections, chronic ulcers, antibiotic activity, neuralgic pain, leprosy); Ornamental
Reinwardtia indica Dum.****	Matkhena	700-1000	Sh	AP	Ind Or	Medicinal (Mouth sores); Fodder
Lythraceae						
Duabanga sonneratioides Buch.-Ham.	-	600-1000	T	Wd	Ind Or	Fuel
Lawsonia inermis L.	Mehandi	500-1000	Sh	Lf, Sd	Orient	Medicinal (Antifertility, burning sensation, headache, pain in muscles, jaundice, sprain, weakness); Miscellaneous (Dye)
*Woodfordia fruticosa (*L.) Kurz.	Dhaw	700-1000	Sh	Lf, Wd	As et Afr Trop	Medicinal (Bone fracture, burns, dropsy, dysentery, sprains, smallpox, ulcer wounds, sprains); Fodder
Malvaceae						
Gossypium arboreum L.	Cappah		Sh			Fibers
Hibiscus rosa-sinensis L.	Gulab	700-1000	Sh	Fl	Afr	Medicinal (Fevers, emollient, aperients, laxative, gonorrhea); Edible; Religious
Urena lobata L.	-	700-1000	Sh	Rt, Lf	Cosmop Trop	Medicinal (Body pain, rheumatism, dysentery, constipation, hydrophobic)
Meliaceae						
Azadirachta indica L.**	Neem	500-1000	T	Lf,St,Bk	Ind Or	Medicinal (Bitter tonic, astringent, ant periodic, antiseptic, ulcers, stomachic, antiseptic); Cosmetic
Melia azedarach L.	Darek	500-1000	T	Fr,St,WP	Ind Or	Medicinal (Wormicide, skin aliments and piles); Timber; Fuel
Toona ciliata M. Roem.	Tooni	500-1000	T	WP,Wd	Austr Malaya	Medicinal (Antiseptic, aphrodisiac, asthma, bone fracture, diarrohea, malaria, dysentery and jaundice); Timber; Agricultural tools; Fodder
Menispermaceae						
Cissampelos pareira L.	-	700-1000	H	Rt	Reg Trop	Medicinal (Antiperiodic, stomachic, carminative, cold, cough, stimulant, diarrhoea, dropsy); Miscellaneous (Mats); Fodder
Stephania glabra (Rox.) Miers.	Galaukadi	700-1000	H	Tu	As Trop	Medicinal (Asthma, dysentery, fever); Fodder
Tinospora cordifolia (L.) Merr.	Giloe	500-800	H	WP	Ind	Medicinal (General disability, dyspepsia, skin diseases, fever, urinary diseases, antibacterial, anti-inflammatory and rheumatism); Religious; Fodder
Mimosaceae						
Albizia lebbeck L.	Sarihn	500-950	T	Bk,Wd	Ind	Medicinal (Tonic, night blindness); Timber; Fodder
A. chinensis Merr.	-	600-1000	T	Wd, Lf	China	Fuel; Fodder
A. julibrissin Durazz	-	600-700	T	Wd, Lf	As Afr Trop	Fuel; Fodder

Appendix 1. Contd

Acacia catechu L.	Khair	600-1000	T	Bk,Wd	Ind	Medicinal (Astringent, betel nut, acidity, stomach pain and antiseptic); Fuel; Timber
A. nilotica L.	Babul	600-1000	T	Fl,Ft,Bk ,Sd	Afr Trop	Medicinal (Asthma, skin disorders, bronchitis and fever)
Mimosa pudica L.	Lajwanti	600-800	H	Lf,RT	Braz	Medicinal (Urinary complaints, glandular swelling, piles); Fodder; Ornamental
Moraceae						
Ficus bengalensis L.	Bargad	700-1000	T	Lf,Bk,Fr	Ind Afr Trop	Medicinal (Antimicrobial, remove mouth ulcers, dysentery); Fodder; Religious
F. palmata Forsk.	Anjiri	700-1000	T	WP	Ind Or Afr trop	Medicinal (Bladder and lung diseases); Wood; Fuel; Edible; Fodder
F. racemosa L.	-	700-1000	T	WP	Ind Or Burma	Medicinal (Cancer, blister, boils, leprosy, muscle pain, piles, dislocation joints); Religious; Fuel; Fodder
F. religiosa L.	Peepal	600-1000	T	Lf, Bk, St	Ind Or	Religious; Fodder; Fuel; Medicinal (Cooling, scabies)
F. roxburghii Wall.	Taryambla	450-900	T	Fr, Wd	As Trop	Edible; Fodder; Fuel
F. rumphii Bl.	-	700-1000	T	Reg Himal	Reg Himal Malaya	Fuel; Fodder; Edible
F. semicordata Buch.- Ham. ex Sm.	-	600-900	T	Fr, Bk	Reg Himal Malaya	Medicinal (Leprosy); Edible
Morus alba L.	Sehtoot	600-1000	T	Fr,Wd,Lf	As Temp	Edible; Fodder; Fuel
Morus serrata Roxb.	Toot	600-1000	T		As Temp	Fodder; Fuel; Edible
Musaceae						
Musa paradisiaca L.	Kela	450-950	H	Fr,Lf	Fr	Medicinal (Stomachic cooling, colitis, digestive, astringent, uremia); Religious; Edible; Fodder
Myrtaceae						
Callistemon citrinus Curtis	Bottle brush	700-1000	T	Fl	Austr	Ornamental
Eucalyptus tereticornis Sm.	Safeda	500-800	T	St, lf	Austr	Medicinal (Cold, astringent); Miscellaneous (Paper)
Psidium guajava L.	Amrood	450-1000	T	Lf, Fr	Am Trop	Medicinal (Mouth sores, anthelmintic, wound infection, in epilepsy); Fuel; Fodder
Syzygium cumini Skees	Jaamun	500-1000	T	WP	Austr Trop	Medicinal (Stimulant, colitis, astringent, antidiabetic, diuretic, dysentery); Agricultural tools; Fodder; Fuel; Edible
S. frondosum (Wall.) Mahaumuni	-	500-1000	T	Fr, Fl. Sd	Ind Or Burma	Medicinal (Stimulant, colitis, astringent, anti-diabetic, diuretic, dysentery); Agricultural tools; Fodder; Fuel; Edible
Myrsinaceae						
Maesa indica Wild.	-	700-900	Sh	Fr	Ind Malaya	Medicinal (Syphilis, women disease); Edible
Nyctaginaceae						
Boerhaavia diffusa L.	Punarnava	700-900	H	Lf, Fl, Rt	Cosmop Trop	Medicinal (Diuretic, laxative, expectorant, asthma, stomach trouble, eye disease and jaundice); Fodder; Edible
Mirabilis jalapa L.	-	900-1000	H	Fl	A Medr Trop	Medicinal (Stomach disorders, tonic, antiseptic, nervous disorders, and aphrodisiac)
Oleaceae						
Jasminum officinale L.	Chameli	500-1000	Sh	Fl, Lf, Rt	Ind Bor china	Medicinal (Antidote to cobra genome, ulcers); Ornamental; Religious

Appendix 1. Contd

Nyctanthes arbor- tristis L.		700-1000	Sh	WP	Ind Or	Medicinal (Ant helminthes, bone fracture, cancer, cough, fever, internal injuries, scale on scalp); Edible: Religious
Oxalidaceae						
Oxalis corniculata L.	Khat mithu	500-1000	H	WP	Amphig Temp Trop	Medicinal (Dyspepsia, jaundice)
Papaveraceae						
Argemone mexicana L.	-	500-1000	H	Fl	Maxic Bor Medr	Medicinal
Papaver somniferium L.	-	500-1000	H	WP	As Trop	Medicinal; Miscellaneous (Narcotic)
Pedaliaceae						
Sesamum indicum L.	Til	450-800	H	Sd,Lf	Trop Afr Ind	Medicinal (Emollient, tonic, diuretic, urinary complaints and burns); Edible; Fodder;
Pinaceae						
Pinus roxburghii Sarg.****	Chir	700-1000	T	Sd,Wd, Res	Reg Himal	Medicinal (Antiseptic, bronchitis, arthritis, neuralgia, rheumatism); Timber; Fuel
Pistaciaceae						
Pistacia integerrima Stewart	Kakarsingi	600-900	T	Sd,Wd	China	Medicinal (Cough, dysentery, eye complaints)
Poaceae						
Apluda mutica L.	**-**	500-1000	H	WP	As Trop Polynesia Austr	Medicinal (Mouth sores); Fodder
Arundinella nepalensis Trin.	-	600-1000	H	WP	Ind Or	Medicinal (Ointment)
Avena sativa L.	Joi	600-1000	H	Sd	Reg Temp et calid	Medicinal (Nerviness, tonic, stimulant, laxative and fungicides); Edible; Fodder
Capillipedium assimile Camus	Tooli-gha	450-800	H	St	Reg Himal China Burma	Miscellaneous (Broom)
Chrysopogon serrulatus Trin.		500-1000	H	Lf	Reg Trop	Fodder
Cynodon dactylon (L.) Pers.	Doob grass	500-1000	H	WP	Cosmop	Medicinal (Dropsy, bleeding piles, gleets, antiseptic, astringent, chronic diarrhoea, dysentery and diabetes); Religious
Dendrocalamus strictus Nees	Bainj	600-1000	T	Rt, Lf, Bk	Ind Or	Medicinal (Antifertility, cough, fever, tonic, veterinary); Edible; Fodder; Religious; Miscellaneous (Making bamboo brakes)
D. hamiltonii Nees	Bainj	600-1000	T	Rt, Lf, Bk	Ind Or	Medicinal (Antifertility, cough, fever, tonic, veterinary); Edible; Fodder; Religious; Miscellaneous (Making bamboo brakes)
Hordeum himalayanse Coel.	Barley	600-1000	H	WP	Ind	Fodder
Hordeum vulgare L.	Jaun	500-900	H	WP	Reg Himal	Edible; Fodder
Oryza sativa L.	Dhan	600-1000	H	WP		Medicinal (Demulcent, dysentery); Edible; Fodder; Religious
Phalaris minor Retz.	Canarygrass	600-1000	H	Lf, St	Oriens, Afr, Austr	Medicinal (Antifertility, cold, cough); Fodder
Saccharum officinarum L.	Ganna	600-1000	H	St, Lf	Reg Himal Burma	Medicinal (Jaundice, blood pressure, demulcent, cooling and diuretic); Edible; Fodder
S. spontaneum L.	Ganna	600-1000	H	Lf	Geront Trop	Fodder; Religious
Setaria glauca L.	-	500-1000	H	Sd	As Trop	Fodder
Sorghum halepense (L.) Pers.	Jowar	500-1000	H	WP		Fodder; Edible
Themeda anathera Hack.	-	700-1000	H	WP	Ins Philip	Fodder
Triticum aestivum L.	Kanak	500-800	H	Sd, AP	USSR (Mid Asia)	Medicinal; Edible; Fodder; Religious

Appendix 1. Contd.

Vetiveria zizanioides (L.) Nash	Khaskhas		H	Rt	Am Bor	Medicinal (Pain, carminative, cooling, colitis, flatulence, diaphoretic, stimulant and anthelmintic); Cosmetic
Zea mays L.	Makka	500-800	H	Sd	Amer	Medicinal (Adhesive, gel antiseptic); Edible; Fodder
Polygonaceae						
Rumex hastatus D. Don	Aambi	800-1000	H	Lf	Reg Himal	Medicinal; Edible
Punicaceae						
Punica granatum L.	Anar	500-1000	Sh	Fr	Europe Austr	Medicinal; Fuel; Edible
Ranunculaceae						
Clematis buchananiana DC.	Chabru	100-1000	Sh	Lf, Fl	Reg Himal	Medicinal; Fodder
Ranunculus laetus Wall. ex D. Don	-	700-1000	H	Lf,Fl	Reh Himal	Medicinal (Conjunctivitis, eye diseases)
Thalictrum foliolossum DC.**	-	800-1000	H	Rt, Lf	Reg Himal	Medicinal (Diuretic, dyspepsia, peptic ulcers, indigestion, fevers, toothache, haemorrhids, boils, pimples and ophthalmia)
Rhamnaceae						
Rhamnus triqueter (Wallich) Brandis****	-	800-1000	T	Bk	Reg Himal	Medicinal (Astringent, antidiarrhoeal, menorrhagia, hypertensive)
Ziziphus mauritiana Lamk.	Jangli ber	600-1000	T	WP	Ind Or Malaya	Edible; Fodder; Religious
Rosaceae						
Prunus armeniaca L.	Khumani	500-1000	T	Fr, Bk, Lf	China	Medicinal (Massage, beverages); Fuel; Fertilizer; Edible; Fodder
P. domestica L.	Alubukhara	600-1000	T	Fr,Wd	Europe Asia	Medicinal (Demulcent, laxative, refrigerant, tonic, heart diseases); Fodder; Edible;
P. persica Batsch	Aru	600-1000	T	Fr, Wd	As Temp	Medicinal (Laxative, purgative, anthelmintic, beverages); Timber; Fodder; Edible; Miscellaneous (Dye)
Pyrus communis L.	Nashpati	500-1000	T	Fr	Europe As Bor Reg Himal	Edible
P. pashia Buch. - Ham.ex D. Don	Kainth	500-1000	Sh	Fr, Wd	Ind Burma	Medicinal; Edible; Fodder; Agricultural tools
Rubus ellipticus Sm.	Aakhae	700-1000	Sh	Fr	Ind	Wild edible, Medicinal (Dysentery, malaria, stomach, worms); Edible
Rubiaceae						
*Hymenodictyon excelsum (*Rox.) Wall.	-	600-1000	T	Rt, Lf	Ind Or Malaya	Medicinal (Abortificant, cholera, fever, gout, lactation, malaria, menalnstral); Edible
Leptodermis lanceolata L.	-	600-900	Sh	Bk, Lf	Reg Himal	Medicinal (Anthelmintic, diuretic, expectorant, liver tonic, jaundice, heat eruption, constipation, colic, cough)
Rubia cordifolia L.****	-	500-1000	H	Rt, St	As Trop et Temp Afr Trop	Medicinal (Tonic, astringent, antipode, dysentery)
Wendlandia heynei (Roem. and Schult.) Sant. and Merch.	-	500-900	T	St	As Trop	Miscellaneous (Toothbrush)
Rutaceae						
Aegle marmelos L. Corr.**	Bael	800-1000	T	Fr, Rt,	Ind Or	Medicinal (diabetes, antiseptic, astringestoma, diarrhoea, dysentery, fevers, narcotic); fuel; religious
C. aurantium L.	Khatta	600-1000	T	Fr	Ind Or	Wild eatable; wood; fuel
C. limon (L.) Burm.f.	Neembu	600-1000	T	Fr	Ind Or	Medicinal (stomachic, carminative, antiscorbic, rheumatism, diarrhoea); eatable

Appendix 1. Contd.

C. reticulata Blanko	Santra	600-1000	T	Fr, Lf,Wd	Ind Or	Medicinal (blood purifier, liver accelerant, thirst tonic, cures catarrh, improve appetite and diarrhoea); fuel; edible
C. sinensis (L.) Osbeck	Mausambi	600-1000	T	Fr, Lf,Wd	Ind Or	Edible; Fuel
Murraya paniculata L. Jack.	Gandhela	500-1000	T	St, Lf,Sd	As et Austr Trop	Medicinal (Stimulant, antiseptic and rheumatism); Miscellaneous (Instruments)
Zanthoxylon armatum DC.**	Tirmir	900-1000	Sh	Sd,Lf	Reg Himal China	Medicinal(Carminative,stomachic,anthelmintic,tonic,disinfectant,antiseptic and gum troubles); Cosmetic
Sapindaceae						
Sapindus mukorossi L.	Reetha	500-1100	T	Sd, Lf	As Trop	Medicinal (Tonic, alexipharmic, anthelmintic, asthma, indigestion, cholera, limb paralysis, Antibacterial and antiseptic); Fodder; Fuel; Miscellaneous (Boxes, combs, carts)
Scrophulariaceae						
Bacopa monnieri (L.) *Penneli*	Brahmi	600-1000	H	Lf	Trop Am	Medicinal (Nerviness tonic, epilepsy, insanity, neuralgia, asthma); Edible; Religious
Verbascum thapsus L.	Janglitambakhu	700-1000	H	Sd	Europe, Afr Reg Himal	Medicinal (Asthma, cough, inflammation, leucoderma, veterinary diseases)
Solanaceae						
Capsicum annum L.	Lalmirchi	500-1000	H	Fr	Reg Trop	Edible
Datura metal L.	Kala datura	600-1000	H	Sh, Rt,Fr	Amer Trop Cosmop	Medicinal (Insanity, skin diseases, antiseptic, nervous disorders); Miscellaneous (Dye)
Lycopersicon esculentum Mill.	Tamatar	600-1000	H	Fr	Am Austr	Medicinal (Tonic); Edible
Solanum indicum L.		500-800	H	Fr	Reg Trop	Medicinal (Asthma, fever, colic)
S. nigrum L.	Makoi	500-1000	H	Fr, Lf, Fl	Amphig	Medicinal (Antidote, boils, cough, dysentery, ear complaints, fever, eye complaints, skin diseases, urinary complaints)
S. melongena L.	Baingun	550-1000	H	Fr	Geront Trop	Medicinal (General stimulant, obits, toothache, ulcers, nose bleed, leave sialagouge, narcotic, cholera, liver diseases)
Withania somnifera Dunal*	Ashwagandha	600-800	Sh	Fr, Lf	Ind Or	Medicinal (Aphrodisiac, tonic, deobstruent, abortive, rheumatism, debility, fevers, hypotonic and diuretic); Edible; Fodder
Tiliaceae						
Grewia asiatica L.	Beul	800-1000	T	Wd,Lf	Reg Himalya	Fodder; Wood; Fiber; Miscellaneous (Ropes)
G. opposifolia Buch.- Ham.****	Beul	900-1000	T	Wd, Lf	Reg Himal	Fodder; Wood; Fiber; Miscellaneous (Ropes)
Ulmaceae						
Celtis australis L.	Khirak	700-1000	T	Lf, Rt, Bk	Europe As Temp Ind Or	Fodder; Fuel
Trema politoria (Planch.) Bl.	-	450-800	Sh	WP	Reg Himal	Fodder; Fuel
T.orientalis (L.) Bl.	-	450-1000	T	WP	Grant Trop	Fodder; Fuel
Urticaceae						
Boehmeria rugulosa Wedd.	-	600-1000	T	Rt	Reg Himal Burma	Medicinal (Rheumatism, gout)
B. platyphylla D. Don	-	600-1000	T	Rt	Reg Himal Burma	Fodder
Urtica dioica L.	Bichoo Booti	900-1o00	H	WP	Reg Bor Temp	Medicinal (Antiseptic, dandruff, dysentery, hematoma, jaundice, sprain, throat disorder)

Appendix 1. Contd.

Valerianaceae						
Valeriana jatamansi Jones	Nihanu	800-1000	H	Fr, Lf, Sd	Reg Himal Burma	Medicinal (Hysterical remedy, nervous unrest, hypochondriacs, carminative, ayurvedic drugs, urinary trouble)
Verbenaceae						
Lantana camara L.	-	500-1000	Sh	Lf, Fr	Am Trop	Medicinal (Itching, malaria, rheumatism, ringworm); Edible; Fuel
Vitex negundo L.	Bana	500-1000	Sh	Wd, Ft, Fr	As Trop Subtrop	Medicinal (Catarrhal fevers, headache, rheumatism, arthritis, antibacterial, tonic, diuretic, anthelmintic, dyspepsia, dysentery, fever and liver complaints)
Violaceae						
Viola canescens Wall. ex Roxb.****	Banafsha	900-1000	H	Lf, Fr	Ind Or Malaya	Medicinal (Asthma, bronchial, cold, cough, eye disorders and malaria)
V. pilosa Bl.	Vanaksa	900-1000	H	Lf, Fr	Ind Or Malaya	Medicinal (Asthma, bronchial, cold, cough, eye disorders and malaria)
Vitaceae						
Vitis parviflora Baker	-	600-900	Sh	St	Reg Or China	Medicinal (Asthma, bronchial, cold, cough, eye disorders and malaria)
V. vinifera L.	Angoor	600-900	Sh	Fr	Ind China	Edible; Medicinal (Boils, toothache, epilepsy); Edible
Zingiberaceae						
Amorphophalus campanulatus Roxb. B.	Jamikand	600-900	H	Tb	Ind Or Himal	Medicinal (Tubers, stomachic, restorative, piles and rheumatic); Edible
Curcuma longa Val.	Haldi	600-900	H	Rh	As Trop	Medicinal (Tonic, carminative, blood purifier, anti periodic, antiseptic, alterative, sprains, cuts, swellings, skin diseases and, bladder diseases); fodder; edible; religious
Hedychium spicatum Sm.**	Ban haldi	600-1000	H	Rh, Lf	Reg Himal	Medicinal (Asthma, blood purifier, bronchitis, nausea); Fodder; Miscellaneous (mats)
Zingiber officinale Rosc.	Adrak	600-1000	H	Rh	Temp	Medicinal (cold infection, restorative tonic, Bronchitis, antinarcotics, antioxidant, stimulant, and carminative)

Lf = Life Form; H = Herb; Sh = Shrub; T = Tree; Lf = leaf; Fr = Fruit; Fl = Flower; WP = Whole Plant; Wd = Wood; Ra = Rasin; Sd = Seed; Bk = Bark; St = Stem; Rh = Rhizome; Tb = Tuber; AP = Aerial Parts; Cl = Climber; Arab = Arabia; Afr = Africa; Am = America; Amphig = Amphigaea; As = Asia; Austr = Australia; Bor = Boreal; Centr = Central; Cosmop = Cosmopolitan; et = And; Geront = Gerontia; Himal = Himalayan; Ind = India; Mongol = Mongolia; Or = Oriental; Orient = Oriental; Reg = Region; Subtrop = Subtropical; Temp = Temperate; Trop = Tropical; Ins = Insular; Malaya = Malaysia; Oc = Occasional; Co = Common; Afghan = Afghanistan; Arab = Arabia; Fr = France; Europ = Europe; Cauc = Caucus; Occ = Occidentalis; Braz = Brazil; Meditr = Mediterranean; Moluce = Moluccan ; Phillip = Phillipine; * = Endemic; ** = Vulnerable; *** = Critically Endangered; and **** = Near Endemic.

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Full Length Research Paper

Analysis of human activities in and around protected areas (PAs): Case of Kakum conservation area in Ghana

Joseph K. Binlinla[1*], Alexey Voinov[2] and William Oduro[3]

[1]Wildlife Division of Forestry Commission, Kyabobo National Park, P.O. BOX 65, Nkwanta, Ghana.
[2]Faculty of Geo-Information Science and Earth Observation (ITC),University of Twente., The Netherlands.
[3]Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

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This study was conducted around Kakum Conservation Area (KCA) to investigate the effect of human activities in 5 km belt of KCA on the ecological functioning and conservation of the PA, as well as effect of KCA on local livelihood. Supervised classification of multi-spectral ASTER imagery was used to determine land-use/cover types in the study area. Open ended questionnaires, group discussions and key informant interviews were conducted among 120 respondents from 40 sampled communities. Classification of the ASTER imagery provided a description of the dominant human activities around KCA. Regression analysis showed that distance was 20% responsible for variance in illegal activities in the PA. Correlation analysis further showed a positive but insignificant relationship between the size of population in communities and illegal activities in KCA. The major impact was from elephant raiding, whereas loss of access to important natural resources was considered as the other significant stressor.

Key words: Ecological functioning, conservation, fringe communities, imagery, classification, illegal activities, land-use/cover types, livelihood.

INTRODUCTION

Tropical landscapes are undergoing rapid anthropogenic changes, particularly in terms of deforestation, with general consequences for climate in the context of targets to reduced emissions from deforestation and degradation (REDD), biological diversity and maintenance of ecosystem services (Kufuor, 2004; Guild et al., 2004; Lauren et al., 2008). Globally, rainforest cover is estimated to be shrinking by about 0.8% per year (Gunatileke and Chakravorty, 2003; Primack and Corlett, 2005). In the course of the last 8,000 years, the Earth's tropical forest cover was almost halved, from 62 million km² to 33 million km² with most of the loss occurring in the last three decades (Achard *et al.,* 2002; Dudley et al., 2002). One major strategy adopted globally to curb the decline in tropical forest is the establishment of a Protected Areas (PAs) network (Myers et al., 2000;

*Corresponding author. E-mail: josephbinlinla@yahoo.com. Tel: +233(0244)960685.

Lawton, 2001). The International Union for Conservation of Nature (IUCN) defines a PA as a geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature, with associated ecosystem services and cultural values (Gaston et al., 2008; Chape et al., 2008).

The world's hundred thousand PAs at present cover over 12% of the earth's land surface, and are known to be the greatest strongholds of biodiversity and landscape conservation (Chape et al., 2008). The establishment of PAs has therefore assumed high priority as the impact of modern industrial society and its expanding demand for resources continues to spread even into the remotest parts of the world (Chape et al., 2008). The World Conservation Monitoring Centre (WCMC, 2008) opined that the establishment of a network of PAs is increasingly important because PAs:

1. Safeguard many of the world's outstanding areas of living richness, natural beauty and cultural significance.
2. Help to maintain the diversity of ecosystems, species, genetic varieties and ecological processes which are vital for the support of all forms of life on earth, and for the improvement of socioeconomic conditions of humans.
3. Protect genetic varieties and species which are vital in meeting human needs, for instance in agriculture and medicine, and are the basis for human socio-cultural adaptation in an uncertain and changing world.
4. Have significant scientific, educational, cultural, recreational and spiritual values.
5. Provide major direct and indirect benefits to local and national economies at large.

Unfortunately, these natural assets are under increasing pressure and threats mainly because of expansion in human demands on the environment, exponential population growth and excessive consumptions (Wittemyer et al., 2008; De Fries et al., 2009; Laurance et al, 2012). Human get attracted to PAs because their surroundings abound in ecosystem services and favourable conditions for agriculture in comparison with outlying areas which remain degraded and less productive.

The main objective of this study was to investigate the effects of human activities on landscapes around Kakum Conservation Area (KCA) on the ecological functioning and conservation of the reserve, as well as effect of the reserve on local livelihood.

MATERIALS AND METHODS

Study area

This study was conducted in and around KCA which is a tropical rainforest PA in the southern part of Ghana in West Africa. It is comprised of two contiguous reserves, established in 1991 and managed as Kakum Conservation Area. Figure 1 shows a map of the study area including the KCA and a 5 km buffer of the adjoining landscape with inset ASTER bands 321 imagery. Portions of the ASTER imagery, marked in red on the map were covered by clouds and could not be analyzed.

KCA covers a total area of 360 km² located between latitudes 5°20' and 5°40' N and longitudes -1°51' and -1°30' W (Hawthorne and Abu-Juam, 1995). The PA forms part of the Upper Guinean Forest in West Africa described among the world's biodiversity hotspots (Myers et al., 2000). KCA experiences two rainy seasons annually (from May to June and September to October). The average annual rainfall is between 1,500 and 1,750 mm (Barnes et al., 2003).

Average relative humidity is about 85% while average temperature ranges between 20.2 and 31.6°C (Barnes et al., 2003). These very favourable climatic conditions work as an additional attractor for further population growth in this area. In particular, the two rainy seasons coupled with relatively high temperatures affords two cropping seasons with considerable farm yields in a year, quite different from other vegetation zones in the country.

Traditionally, the entire landscape belongs to Assin, Twifo Hemang, Denkyira and Abura-Asebu Kwaman-Kese states. Citizens of the various states have lived in the area since the beginning of the 20th century, mainly engaged in agriculture. Besides, the locals supplemented their livelihood needs with hunting and other non-timber forest products (NTFPs), which they collected without restrictions. This situation continued until 1991 when KCA was established as a PA and as such access to resources within its confines became restricted (Eggert et al., 2003). However the locals continued to engage in small scale farming on the fringes of the PA. Around the late 1980s onwards, the cocoa industry in Ghana received a boost from the government through control of diseases, increased producer prices and other incentives for production (Kees Van and Vrieling, 2010). These conditions facilitated movements of people from regions with small patches of remaining forests to regions with relatively large stock of forest with favourable ecological conditions for cocoa cultivation. Landscapes surrounding KCA experienced influx of migrant cocoa farmers from other regions of the country and this culminated in rendering the PA an island in the "sea" of cultivated landscapes.

Field work

Field work was carried out in September-October 2010. Data was collected through random sampling method. Sample of the communities, poachers' arrest and poaching trails, data on elephant crop raiding in farms on adjoining landscapes and demographic and socioeconomic data for sampled communities were collected through questionnaire survey. Ground truth data and illegal human activities were collected through line transects in KCA.

The landscape was divided into 10 rectangular sampling plots of 5 x 5 km², based on geographic coordinates in the area. This was in order to ensure equal representation for the different communities in the sampling scheme. The scheme was particularly to take care of minority groups as well as people of varied ethnic and cultural background in the area. This scheme was also used in collecting ground truth points. A list of all communities within each of the plots was generated and 4 randomly selected from each plot. This generated a sample size of 40 communities from which respondents were further sampled for administration of questionnaire.

Questionnaire surveys

Semi-structured, open ended questionnaires were designed and field surveys conducted in 40 sampled communities. In all 120 respondents (3 from each of the 40 communities) were interviewed,

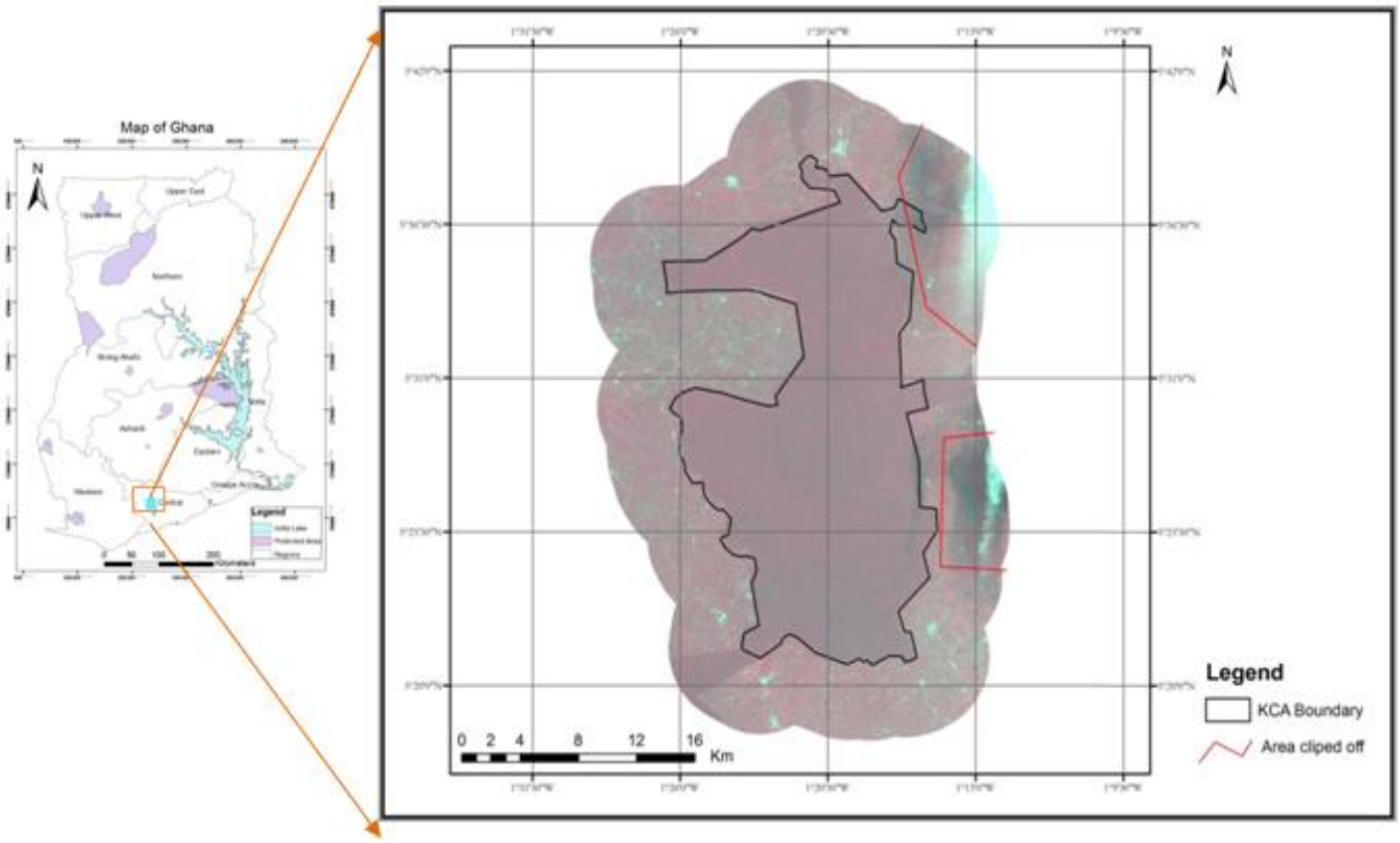

Figure 1. Study area: Kakum conservation area (KCA).

109 males and 11 females. The interviews were conducted in the local dialect of respondents (Twi). Focused group discussions and key informant interviews were held in some communities to clarify specific responses. Respondents were identified through simple random sampling procedure by means of a ballot.

Illegal activities encountered along transects in KCA

Signs of illegal activities were recorded along forty transects into the PA. Geographic locations of sampled communities and their mean distances in relation to the PA were determined. A one kilometre transect was laid in the PA perpendicular to the location of each sampled community, and all signs of illegal activities encountered along transects were geo-referenced with the help of a hand held GPS device. The procedure was the same for all 40 transects along the 40 sampled communities. Because of the relatively large area to be covered and because of time constraints, it was decided not to cut straight-line transects through the PA. Instead transects of least resistance were employed (Sam, 1996). Rangers and patrol staff of KCA assisted in the collection of these data, mostly because of their technical knowledge in identifying and distinguishing between types of illegal activities, as well as serving as field guards during the forest hike. In all 233 different incidents of illegal activities were encountered, ranging from hunters' trails, cartridge shells to cutting of raphia palms (*Raphia farinifera*). Mean distances of communities from the PA and number of illegal activities encountered along each corresponding transects were analyzed statistically in order to determine their correlation.

Satellite image classification

Within the scope of this study, image classification is defined as the extraction of distinct themes, from ASTER 2007 imagery based on image pixels. Because of the researcher's familiarity with the study area, supervised classification method with Maximum Likelihood classifier algorithm (Hubert-Moy et al., 2001) was used, providing high classification accuracy. Whereas image classification produced a land cover map of the study area for determination of land use cover types in place, the purpose for field data was to understand the socio-economic and cultural dynamics of the sampled communities.

RESULTS

The existing land-use/cover types around KCA

Supervised classification of multi-spectral ASTER 2007 imagery categorized the study area into five major land-use/cover types, namely: forest, oil palm plantation, mixed crops, cocoa farm and built-up/bare. Forest refers to the protected area and small patches of fallow lands around. The four remaining classes are the dominant land-use and cover types around the fringes of KCA. However portions within KCA showed the other four cover types, other than forest, after classification. Based

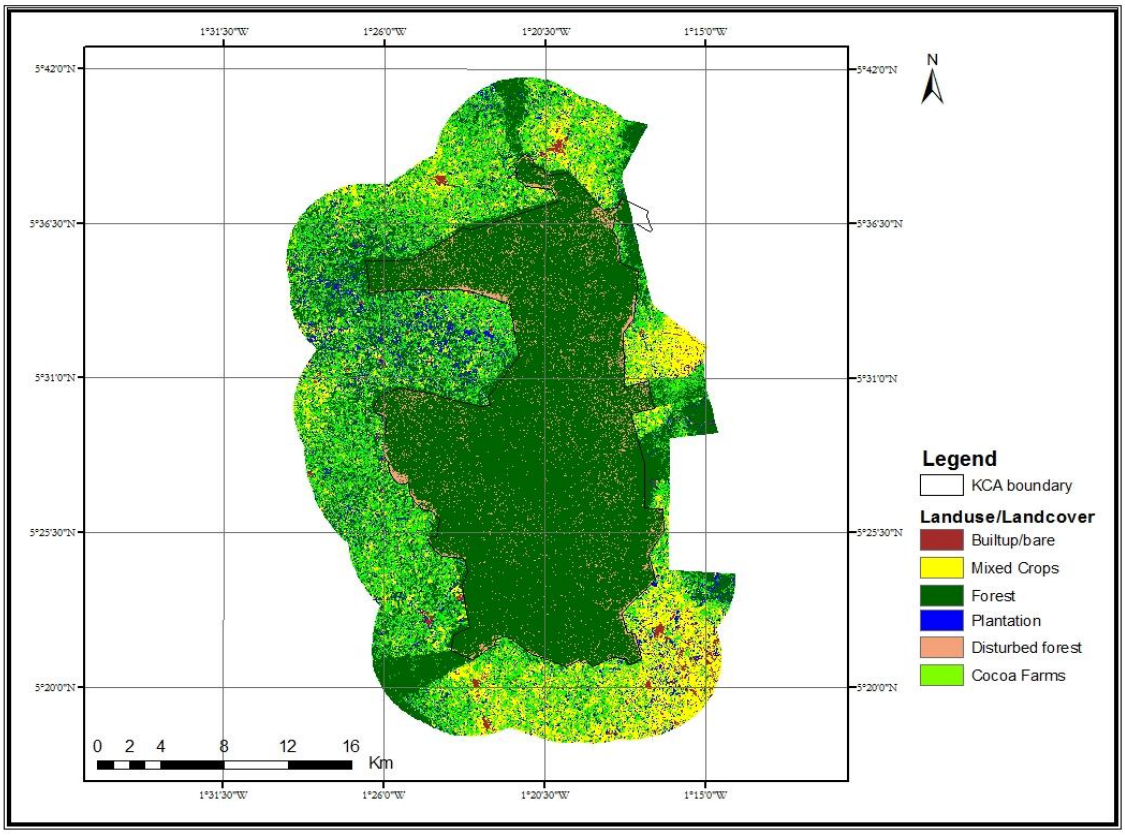

Figure 2. Land cover map of study area.

Table 1. Description of land-use/cover types in the study area.

Land cover type (class name)	Descriptions
Forest	Forested areas predominantly covered by trees with or without close canopy. It includes KCA and fallow lands in the surrounding landscape.
Oil palm plantations	Areas predominantly covered with oil palm plantations *(Elaeis guineensis)* on the fringes of KCA
Mixed crops	Areas covered with a mixture of crops that include maize, plantain, cocoyam and cassava on a single plot of land on the fringes of KCA.
Cocoa farms	Areas predominantly covered with matured cocoa (*Theobroma cacao*) trees along the fringes of KCA
Built-up/bare	Areas dominated with buildings, roads and other human infrastructure, as well as exposed soils resulting from human activity or natural cause.
Disturbed forest	Areas of forest inside KCA that classified other forest and are likely results of disturbances by humans, including tree removal, clearing, fire or cocoa farms.

on expert knowledge these non-forested land-uses inside the PA were grouped and labelled disturbed forest, (Figure 2). These include human induced disturbances such as illegal cocoa farms and illegally felled trees among others.

The categories are elaborated in Tables 1 and 2. The resulting land cover map specified dominant use of the landscape and a basis for analyzing effects of human activities on biodiversity in and around KCA. The map shows the extent to which habitats in the neighbouring landscapes have been converted from forested ecosystems into varied land-use/cover types, and thus demonstrating the negative effects of human activities on biodiversity in and around the PA.

Clearly, the intention of most farmers on the fringes of KCA is to grow cocoa as observed from analyses of land cover types, (22% of land under cocoa in relation to other crops). Partly, this is because of government interventions

Table 2. Land-use/cover types and size covered in the study area (ha).

Land cover type (Class name)	Land use	Description	Percentage
		Area covered (ha)	
Forest	Conservation area/fallow patches	43,764.8	49.5%
Cocoa farms	Farm land	19,570.43	22.1%
Mixed crops	Farm land	14,686.18	16.7%
Oil palm plantation	Farm land	4,505.06	5.2%
Built-up/bare	Settlement/bare areas	1,440.88	1.6%
Disturbed forest	Farms and other illegal activities	4,263.72	4.9%
Total area		88,231.69	100%

Table 3. Accuracy assessment report.

Class name	Reference total	Classified total	Number correct	Producer's Accuracy (%)	User's Accuracy (%)	Kappa
Forest	89	89	79	88.76	88.76	0.82
Plantation	21	22	16	76.19	72.73	0.70
Cocoa farms	70	72	60	85.71	83.33	0.77
Mixed crops	57	55	45	78.95	81.82	0.76
Built-up/bare	18	17	13	72.22	76.47	0.74
Total	255	255	213			

Overall accuracy = 83.53%; overall Kappa statistic = 0.77.

that have boosted production of the crop in the country, and perhaps also because perhaps cocoa in Ghana is widely considered among farmers as an important security at old age. The average size of a cocoa farm ranges between 7 and 8 ha. Cocoa farms are generally difficult to distinguish and accurately classify when located within a forest because of similarity in their spectral reflectance with pristine forest (Rice, 2000). However, in the case of this study, cocoa farms had relatively high classification accuracy (Table 3) as a result of the fact that they are located entirely outside the borders of the PA, invariably with no forest trees found in them.

Again the high accuracy could be attributed to the large number of ground control points collected for validation during field work. Whereas outside the PA most of the impacted forest is indeed replaced by cocoa, it is pretty difficult to conclude that the situation is the same inside KCA. Again, the overall classification accuracy was quite high as observed in Table 3. However, classification errors are likely to be caused by misclassification of some pixels

The cultivation of mixed crops mainly maize, cassava, plantain, cocoyam, vegetables, usually planted together on a single plot, is common among farmers, meant for subsistence and occasionally for commercial purposes. Mixed crop fields are smaller in sizes as compared to cocoa, they range between 0.2-3.0 ha on average and are located in between cocoa farms and palm plantations.

Cultivation of oil palm plantation has recently gained popularity in the area as a commercial crop mainly for palm oil extraction, even though not much of the landscape is committed to it as to the cultivation of cocoa. Settlements in the area constitute various types ranging from hamlets, cottages, small towns to sizeable communities mostly built with local materials. The landscape was also covered with very small fallow lands and patches of uncultivated lands.

Some of these landscapes were left uncultivated because elephants from the PA habitually raided crops on them. Other fallow lands in the area remained uncultivated as a result of petty land disputes between some farmers. These small patches of fallow landscapes were classified as forest.

Demographic characteristics of the study area

Demographic data for the study communities for 1970, 1984 and 2000, was obtained from the Ghana Statistical Services (GSS 2000) and growth rates were calculated to analyse population growth trends. Table 4 shows population growth trends in Ghana and in the study communities. Population growth rates were derived using the population growth rate formula, r =

Table 4. Comparison of population growth trends (1970 - 2000).

Year	Population in Ghana (million)	Average growth rate in Ghana (%)	Population in study communities (thousand)	Average growth rate in study communities (%)
1970	8,559	2.2	5,461	3.2
1984	10,736	2.5	10,524	3.4
2000	18,412	2.3	21,749	4.8

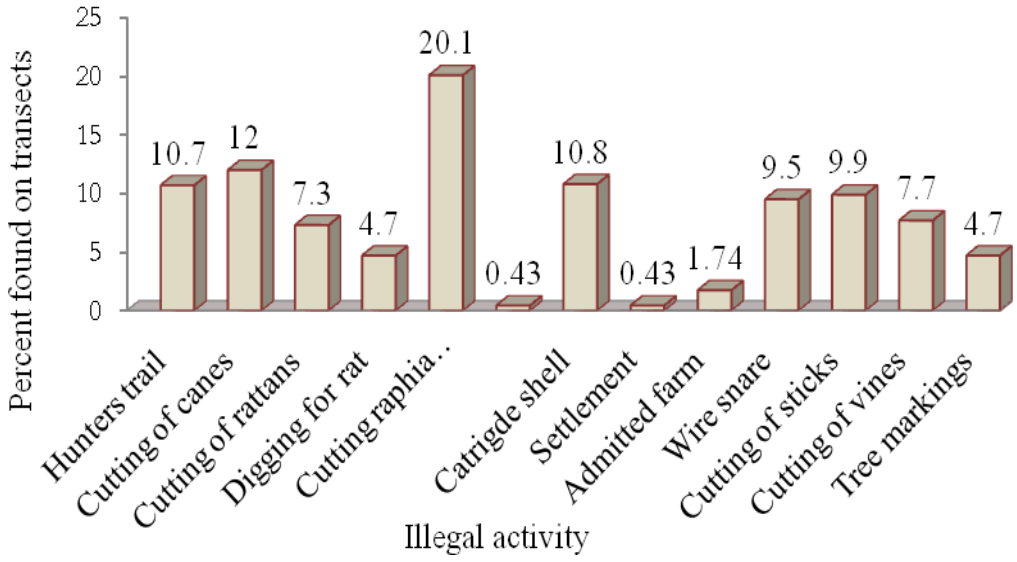

Figure 3. Percentage of types of illegal activities along transects in KCA.

$(P^1 - P^0)/P^0 * 100/t$ where, r = average annual rate of growth, P^1 =current population totals, P^0 = previous population totals, t = the number of years between censuses (Witmeyer et al., 2008).

Comparison of population growth trends between 1984 and 2000 showed that the environment of KCA had more people during the period after its creation in 1991 than before, growth rates increased by 0.8% after creation of the PA.

There was no such increase in population growth rates for the country as a whole. Growth rates for KCA were higher than the 2.4% average for the nation (2.1% for the Central Region and 3.6% for other rural areas during the same period.

Effect of land-use types on the ecological functioning and biodiversity conservation in KCA

Accelerated growth in human populations around KCA has been identified as a major threat to the PA (IUCN/PACO, 2010). As observed from the land cover map, increased human population on the fringes of KCA resulted in habitat conversion of the bordering landscape as well as human disturbances within KCA. Apart from disturbed spots within the PA, a number of other illegal activities were encountered along transects into the PA.

A total of 233 signs of illegal activities were recorded along the forty transects in KCA. Of these activities harvesting of raphia palm (*Raphia farinifera*) was most frequent with 20.1% occurrence (Figure 3).

This is probably because of its extensive use by the locals as building material for their mud houses. Land clearing for agriculture coupled with competition for the harvest of raphia on the fringing landscape is reported to have completely wiped-out the resource outside of the PA. Therefore illegal harvest of raphia and other building materials within the confines of the PA is a common practice among locals in the study area.

Cane cutting constitutes the next highest finding with 12% occurrence, followed by cartridge shells with 10.8%. Communities around PAs often engage in bushmeat hunting for both commercial and subsistence purposes. Other illegal activities encountered include cutting of sticks, vines *(Berchimia scandens*), and rattans constituting 9.9, 7.7 and 7.3%, respectively. Canes and rattans are harvested and used in weaving baskets for

Table 5. Comparison of mean distance and illegal activities in KCA.

Community	Population in 2000	No. of illegal activities along transects	Percentage	Mean distance from KCA (km)
Aboabo	532	17	7.2	0.20
Adianum	299	15	6.4	0.80
Antwikwaa	479	5	5.1	0.50
Nkwantanaan	398	12	5.1	0.80
Gyahadzi	76	7	3.0	0.30
Apokwaa	184	8	3.4	0.80
Briscoe I	389	6	2.6	0.10
Mpentemboa	56	5	2.1	0.10
Nsabaa	108	10	4.3	0.90
Obengkrom	156	8	3.4	0.70
Adwe krom	543	7	3.0	0.40
Essuman	243	7	3.0	0.20
Fa Asem Kye	421	9	3.8	0.30
Mesomagor	395	7	3.0	0.70
Adwe-krom	543	7	3.0	0.40
Akosua Doma	432	5	2.1	0.50
Asem Asa	593	5	2.1	0.50
Boafo Yena	718	6	2.6	0.20
Nyarko	203	6	2.6	0.20

carrying cocoa pods and other foodstuffs from farm.

Illegal activities in KCA related to location of fringe communities

What drives illegal activities in the protected area? Our hypothesis was that it is related to the human population residing in the area. Therefore, the next step was to explore the relationship between the number of illegal activities in KCA and the size of human settlements and their location.

First, we looked at the correlation between the mean distances of communities from KCA and the number of illegal activities encountered along transects.

Correlation yielded R = -0.446, p< 0.004 implying a negative correlation between the two variables, the farther communities are from KCA the less illegal activities observed. A regression statistics (ANOVA, single factor) of R^2= 0.20 at p < 0.05, implied 20% of the total variance in dependent variables (illegal activities) could be explained by the independent variables (mean distances). From analyses, communities located close to KCA (between mean distances of 0.10 and 0.90 km) recorded high numbers of illegal activities in KCA. Aboabo community has a mean distance of 0.20 km from the boundary of KCA and recorded 17 or 7.2% of illegal activities in comparison with Kruwa with a mean distance of 1.9 from the PA boundary and recorded only 3 or 1.3% of illegal activities.

Illegal activities were again correlated with the number of people in each community. Population data for the 2000 population and housing census were used for this analysis. Projection ratios for the 2000 population could have been used to represent population figures in 2010 for these analyses. However, demographers often criticize projection ratios for their validity (Voss and Balkrishna, 1992). Hence, we used the 2000 data and produced a positive but very insignificant correlation R = 0.068, p > 0.698. A regression statistics of R^2 = 0.04, at p < 0.05 (Table 5).

Communities with relatively high population figures recorded marginally low levels of illegal activities, and at the same time these communities are located between mean distances of 1.0-2.0 km from the borders of KCA (Table 6).

The following inferences could therefore be drawn in relation to fringe communities and encroachments within KCA by comparing Tables 5 and 6:

1. Communities that are located closer than 1 km to the borders of KCA are relatively smaller and tend to encroach more in the PA although distance was found to be only 20% accountable for the variance in illegal

Table 6. Comparison of population and illegal activities in KCA.

Community	Population in 2000 (000)	No. of illegal activities along transects	Percentage	Mean distance from KCA (km)
Adiembra	1,987	3	1.3%	1.5
Ahenbrom	1,988	4	1.7%	1.0
Abodweseso	976	2	0.9%	1.3
Nyamebekyere	945	1	0.4%	2.0
Homaho	1,182	3	1.3%	1.0
Mfoum	2,910	5	2.1%	1.8
Kruwa	1,972	3	1.3%	1.9

activities;
2. Communities with relatively high human populations also encroach more in the PA but at a marginally low rate (only 4% responsible for the variance in illegal activities), and invariably located more than 1 km from the PA;
3. Communities located farther than 1 km from KCA generally encroach less on the PA perhaps as a result of their mean distances from the PA.

Therefore, distance at which a community is located from KCA was found to be more accountable in explaining levels of human encroachment in KCA than size of population. Figure 4 illustrates location of illegal activities and sizes of sample communities in a population density map of the study area. Apparently, it is the smaller but closely located communities that have the largest impact on the KCA. One possible explanation is that the bigger the community the more economic fortunes it attains and therefore the less it depends on NTFPs and other resources directly provided by the PA.

Population levels and impact on KCA

Analysis of human populations showed that communities around KCA before its creation experienced average growth rate of 3.3% as compared to a higher average growth rate of 4.1% after its creation in 1989. Average growth rate for the same period for the entire country remained at 2.4 and 3.6% for other rural areas. This study has demonstrated that land-use and habitat conversion around KCA is driven mainly by population growth. Growth in population resulted in varied uses of the landscape including conversion to agriculture and settlements with diverse impacts on ecological processes in and around KCA.

Analysis of encroachers arrested in KCA

To enhance PA security, the staffs employ conventional law enforcement in the form of armed foot patrols within KCA. Invariably, the essence is to safeguard the ecological integrity of the PA through regular day, night, short, long and in some cases, emergency foot patrols, surveillance and monitoring operations against any illegal activity. In order to compare encounter rates of illegal activities within PAs a standardized measure of patrol effort is used (Hood and Parker, 2001). A measure of efforts for comparing areas with each other as applied in the case of KCA is effective patrol man days (EPMDs) per unit time (Jachmann, 2008). While on patrol, staff records geographic location of patrol areas with the aid of GPS and compass devices. With the same devices they also record illegal activities by encroachers, animal sightings and other events of interest. Figure 5 shows numbers and percentages of arrests made by field staff in KCA between 2002 and 2009, thus validating occurrence of illegal activities in KCA.

2004 recorded the highest numbers of arrests of 45 poachers. This was reportedly because of the introduction of a new measure of patrol efforts at the start of 2004 known as the effective patrol man-days per unit time (Jackmann, 2008). Arrests declined sharply to 6 the following year probably because the locals may have gotten wind of the new system and arrests made the previous year, and so decided to temporary withdraw. Otherwise new poaching tactics might have been devised, through which poachers could outwit patrol staff. Arrest rose again to 24 in 2006, 32 in 2007 and again fell to 30 in 2008. Wildlife poaching in particular has been identified as a persistent illegal activity in forest reserves (Jackmann, 2008). In particular, commercial poachers are noted for making use of a network of trails they create, often walking long distances into the PA. Others are described as “hit and run” poachers who hunt in the PA without necessarily using the trails net-work. The second group of poachers are those who hunt purposely for subsistence. They usually sneak in to the PA and once inside begin to mark trees and saplings as signs to enable them determine their way out, and on shooting an animal quickly move out with the booty without staying long in the PA.

Effects of KCA on local livelihood

Reponses from questionnaires revealed that the settler

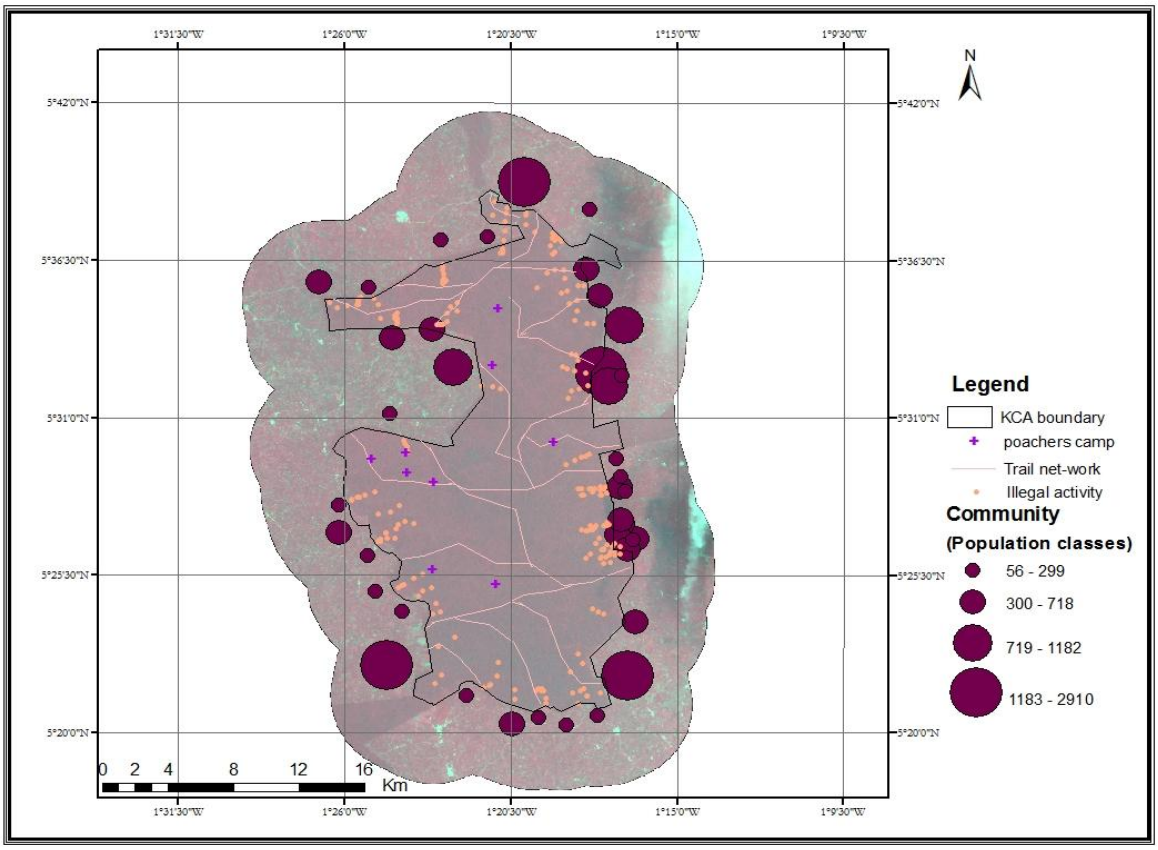

Figure 4. Distribution of population and illegal activities along transects in KCA.

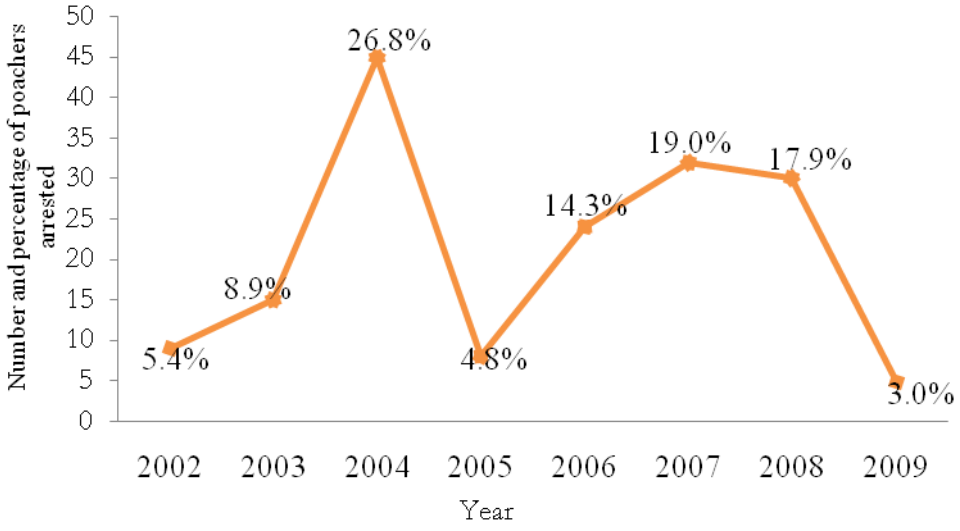

Figure 5. Percentage of poachers arrested in KCA (2002 to 2009). Source: (Poachers arrest record in 2010, offices of KCA).

group comprises of 10 different tribes in the country who originate from 7 out of the 10 regions. These revelations are further evidence of movement of people from other regions of the country into the study area. Ultimately, high population growth rates around KCA resulted in the following impacts, according to respondents: (1) widened

Table 7. Analysis of responses generated from community surveys.

Description	Frequency		Percent		Total (N)
	Yes	No	Yes	No	
Knowledge in wildlife and biodiversity conservation	102	18	85%	15%	120
Ever collected NTFPs from reserves	81	39	67.%	33.%	120
Ever suffered from wildlife crop raiding	110	10	92.0%	9.0%	120
Tangible benefits from PA	0	120	0	100%	120

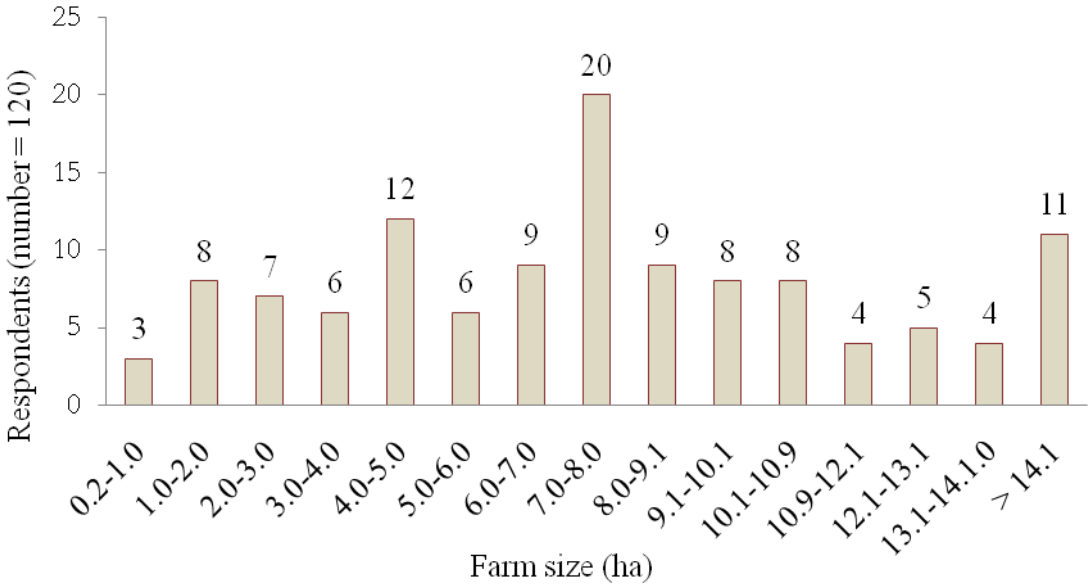

Figure 6. Distribution of farm sizes around KCA.

'people-PA' frontier, the area where the interaction and conflict between people and the PA is pronounced; (2) increased competition for arable land and natural resources in the area; (3) loss of habitat due to land conversion; (4) increased human-wildlife conflicts and, (5) further encroachment in KCA (Barnes et al., 2003; Eggert et al., 2003). The analyses are shown in Table 7.

Until the later part of 1989, the areas that constitute KCA were forest reserves managed purposely for water catchment protection and timber production (Barnes et al., 2003). As forest reserves at that time, they were open for the locals to access and gather assorted NTFPs. Forest products such as bushmeat, fibres, berries and roots in particular served as food and dietary protein supplements, and other products as building materials for the construction of mud houses and medicinal plants for herbal health care needs. The source of such freely available ecosystem services ended from 1991 when KCA was established as a wildlife PA. 67% of respondents reported having gathered forest products from the PA in the past for direct household consumption and also as a source of income and employment. 37% of respondents identified loss of NTFPs from KCA as a major concern in its establishment and according to respondents, as a reason to increase their farmlands in order to compensate for income previously derived from sales of NTFPs and other resources.

Both groups of respondents are engaged in commercial and subsistence farming, mainly on the landscapes around KCA. Reported farm sizes range between 0.2 ha - >14 ha (Figure 6), with the average farm size ranging between 7.0-8.0 ha for cocoa and 0.2-3.0 ha for mixed crops.

Incidence of elephant crop raiding on landscapes around KCA

Respondents confirmed that farmers around KCA suffered elephant raids on farms during the period when the PA was not established. However, frequency of crop raiding, number of farms and crops affected increased

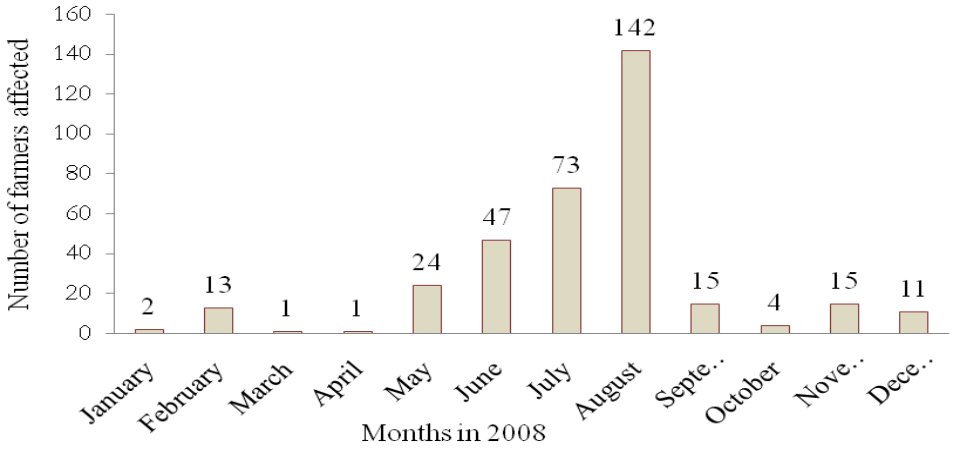

Figure 7. Incident of crop raiding around KCA in 2008. Source: (Crop raiding report 2008, offices of KCA).

after the creation of KCA (Eggert et al., (2003). Barnes et al. (2003) inferred that increased reports of crop raiding in the study area are evidence of widened human-elephant interface due to increased human population. This may also be a result of increased numbers of wildlife in PAs, which, supposedly, is a positive development, but not for the surrounding farmers.

As a result of the situation three international organizations; the Food and Agriculture Organization (FAO), the World Bank and the International Fund for Animal Welfare (IFAW) intervened in 2004, 2006 and 2008, respectively, to assist the farmers protect crops from elephant raids in particular (Addo-Boadu, 2010; Monney et al., 2010). Although farmers considered the interventions as a welcome relief, adoption rates are reportedly low among farmers mainly because of the cost involved in its application (Monney et al., 2010). As such, farmers in the area continue to experience elephant crop raiding (Figure 7).

A total of 348 farmers suffered crop raiding in 2008. Raiding is usually low at the start of the year then increases from the month of May. The peak raiding months are June to August, at times up to September depending on rainfall patterns experienced in the year. Raids involved food crops such as maize, cassava, plantain, cocoyam to tree crops including cocoa and citrus. Crop raiding impacts more on the locals because the state does not compensate for wildlife depredations in the country. This is also because compensation scheme may end up attracting more migrants into the area to re-fuel the very cause of the problem.

DISCUSSION

It appears that with no buffer zone established for the PA, such a 'fringe people-PA' frontier is developing by itself as a result of some on-going interaction between the natural, Protected Area and the rapidly developing human landscapes.

Illegal activities are a major concern in biodiversity conservation. Their biological impacts range from declines in genetic diversity and species richness to changes in community composition and ecosystem services (Benjaminsen *et al.,* 2013). Illegal activities such as bushmeat hunting and land clearing in particular impact rainforest by wiping-out wildlife (in particular mammals and birds) that are important for dispersing tree species. The situation changes the structure of forest species by favouring small-seeded trees over large-seeded, leading invariably to lower tree diversity and hence degradation of forest landscapes (Holmerm *et al.,* 2007).

Effects of habitat conversion on biodiversity conservation in KCA

Human disturbances on the surrounding landscape have impacted KCA negatively as shown by the land cover map. There is active poaching of animals as seen from the number of cartridge shells and wire snares found along transects. Such disturbances impact wildlife species within the PA by destroying their territorial areas and driving them into the converted adjoining landscapes. Landscapes that adjoin PAs could play important roles in sustaining ecological functioning in and around PAs (Hansen and De-Fries, 2007).

These landscapes invariably serve as source areas for populations of species in the PA; provide habitats for species with larger home range and migratory routes for particular species of fauna (Laurance et al., 2012). In this regard, the natural cross-boundary migration of flora and fauna species between KCA and the adjoining land-scapes is adversely affected by conversion of landscape around PA to agricultural or residential uses.

Effects of KCA on community livelihood

Effects of KCA on local livelihoods could be discussed from two main points of view: 1) loss of access to land and forest products, 2) wildlife depredations on croplands.

Human Development Index (HDI), by the United Nations Development Programme (UNDP) estimates that 90% of the world's poor depend on forests for at least a portion of their income (World Bank, 2004; USAID, 2006). In Africa, about 600 million people have been estimated to rely solely on forests and woodlands for their livelihoods (WRI, 2005). Shackleton and Shackleton (2004) opined that depending on circumstances, forest products may offer both a "daily net" and a "safety net". The "daily net" describe everyday use, with product meeting current household needs as well as offering a reliable source of income. A 'safety net' on the other hand comes into play when other sources of household income, fail to meet dietary shortfalls, or whenever a quick cash option is required (McSweeney, 2003). To these end, loss of access to NTFPs in the case of KCA implies adverse effects on livelihoods of the locals, even though the net livelihood impacts are generally less easy to discern, mainly because of the lack of standardized assessment methodologies (Shackleton and Shackleton, 2004).

Wildlife challenges encountered by communities living close to PAs fall into two main categories: damage to resources such as crop raiding and livestock predations, and threats to human life by wild animals from the PA. In the case of KCA, the challenge is crop-raiding mainly by elephants migrating from the PA. This challenge was however, identified as a symptom of the ecological changes that have taken place on landscapes bordering KCA, resulting from increased human populations in recent decades. According to Sillero-Zubiri et al, (2004), larger animals such as forest elephants (*Loxodonta africana cyclotis*) typically require larger home ranges and more food resources to sustain a viable population. This pushes them to extend their range beyond the limits of PA boundaries into neighbouring lands, thereby entering into conflicts with local communities as in the scenario with resident elephants in KCA.

Conclusion

Analysis of population growth around KCA showed that growth rate increased by 0.8% after the park's establishment. The increase in population was mainly a result of migration of people from other regions in the country into the study area to engage in agricultural activities. Human activities around the PA resulted in habitat conversion on the surrounding landscapes, which reduced the effective size of the ecosystem, produced edge effects, caused human encroachment and affected the ecological processes in KCA. Indeed, statistical analyses showed negative correlation between mean distance of communities and number of illegal activities in KCA.

On the other hand, local livelihood are adversely affected by the PA because of unattainable forest products and raiding by wildlife from KCA. The magnitude of raiding effects on locals can be exemplified in the instance of a farmer who loses a whole season's produce to a herd of elephants overnight because he/she genuinely lacked the means to protect the crops from elephants. With no compensation for the loss and no access to products from KCA or alternative sources of livelihood, the farmer and his dependants are left impoverished for the period. In particular, the lack of access to forest products in KCA implies that source of direct household income, consumption and employment have been affected adversely due to creation of KCA. Also, traditional socio-cultural and religious ties with the forest as known for forest fringe communities are broken. Inaccessibility to bushmeat in particular results in reduced levels of dietary protein among families in the area or scarce cash will have to be spent to meet protein requirements. Consequently, the severity of these effects on the locals breeds apathy and community/park conflicts further make the PA unsustainable as biodiversity conservation area.

It may not be wise to establish PAs without a designated buffer zone, which would allow a softer transition between natural, wildlife dominated areas and developed human dominated ones. With no legally designated buffer zone, it still manifests itself, but with inevitably associated conflict: arrests in the PA, as well as wildlife raiding outside the PA. Establishing a buffer zone with restricted human activities, instead of total protection, could help avoid a good deal of conflict and make PAs more welcomed by local people.

It has been shown that system sustainability is a hierarchical feature, which has to be analyzed at a variety of scales (Voinov and Farley, 2007; Voinov, 2008). Gaining in sustainability in one scale may come at the expense of sustainability of sub- or supra-systems. Establishing PAs is crucial for regional and global biodiversity and conservation. Locally, PAs may however have adverse effects, especially when they are not planned and managed appropriately. We have shown that KCA has produced a "pull-effect" attracting even more human population and demand to an area where it is least desired. Lack of a buffer zone and repeated crop-raiding instigated by the park further impacts the human population, creating more unrest and hostility toward the idea of conservation. The promise of ecotourism also comes with big social and economic disparities, where the most impoverished groups of people are the least likely ones to get any benefits from it (Liu et al., 2012).

PAs have many forms of direct and indirect benefits at both local and global levels in the form of gains from the

opportunities for recreation and renewal from the genetic potential of wild species, as well as the environmental services provided by natural ecosystems. Biodiversity conservation should however not be at the expense of local communities whose livelihoods have depended to a very large extent, on forest and biological resources in terms of materials essential for basic life sustenance. As much as possible, some level of local community needs and aspiration ought to be integrated into PA management systems to enable local and fringe communities truly buy into the model of biodiversity conservation, particularly within African countries. In this regard, parks that generate revenue in the form of eco-tourism, sport hunting and more recently from unfolding carbon trade concept, should be made to support locals through creation of sustainable livelihood schemes and provision of basic infrastructure. The concept of Integrated Conservation and Development Projects (ICDPs Report, 2005) may well be acceptable means of reducing the "trade-offs" felt by local communities in terms of loss of access to resource.

Local communities should be integrated more into PA management and development programmes, thus for more impartial governance of "their" natural resources by devolving decision-making and resource control to local populations such as the Community Resource Management Area (CREMA) concept being introduced by the Wildlife Division in Ghana. It is clear that the future of wildlife and biodiversity conservation, will depend to a large extent on its capacity to deliver tangible incentives to local people, and the most effective way to deliver such incentives is to accord them the ownership right and the responsibility to manage biodiversity, and not purely on the strength of prohibitive rules and regulations.

Such conscious initiatives may go a long way to balance and enhance human welfare needs and ecological functioning.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Impact of *Tithonia diversifolia* (Hemsly) A. Gray on the soil, species diversity and composition of vegetation in Ile-Ife (Southwestern Nigeria), Nigeria

Agboola Oludare* and Joseph I. Muoghalu

Department of Botany, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

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In Nigeria, most especially in the southwestern region, *Tithonia diversifolia* (Hemsly) A. Gray had been identified to be invasive following their introduction and fast spread, displacing the native species and affecting the soil nutrient status. Hence, we decided to evaluate the impact of *T. diversifolia* on the diversity and floristic compositions of native species and soil nutrient status of the invaded vegetation. Sample plots, 5 x 5 m each were established on invaded and uninvaded area in 10 sites in area invaded by *T. diversifolia*. In each plot, plant species enumeration was done to the species level and species diversity, evenness and index of similarity were evaluated. Soil samples were randomly collected at depth 0-15 cm and analyzed for chemical properties (pH, organic carbon, exchangeable cations (Ca, Mg, K and Na), nitrogen and phosphorus). One way ANOVA was used to determine significant difference in soil properties on invaded and uninvaded plots. The result showed that as compared to the control, in the *Tithonia* invaded area, the average number of plant species reduced by 25.4%; the Shannon-Wiener diversity reduced by 27% while the evenness reduced by 24.9% and the Sorensen index of similarity between the invaded and uninvaded plots for *Tithonia* was 32.6%. The invaded plots had higher pH, organic carbon, N, P and exchangeable cations than the uninvaded plot (p=0.05). We concluded that invasion of *T. diversifolia* is drastically affecting the diversity of the invaded areas and had significantly improved the soil fertility of the invaded sites.

Key words: Invasive species, biological diversity, Shannon-Winner.

INTRODUCTION

The biota of the world is being homogenized as a result of the decline of native species and their replacement by a relatively small number of alien species that either deliberately or accidentally moves beyond their natural ranges (McKinney and Lockwood, 1999). These invasive alien species have encroached into many ecosystems and communities throughout the world, disrupting ecosystem structure and function and, thus, reducing native biodiversity (Borgmann and Rodewald, 2005). These outcompete native species or occupy the available niches in

*Corresponding author. E-mail: dipod2001@yahoo.com.

alien environment (Cowie, 1998) and cause major economic loss in countries around the world, by decreasing growth and productivity of useful species (Pimentel et al., 2000). The increasing rate of invasion and deliberate introduction of aliens into an area by man is the by-product of the globalization of regional economics. Large parts of the world are presently dominated by human modified ecosystems that often comprise a greater biomass of introduced than native organisms (Vitousek et al., 1997). Besides human actions, several other factors contribute to successful invasion by alien plants. The climatic and edaphic similarities between the original and new habitats are very important factors for the establishment of such species (Holdgate, 1986). Biological invasion are clearly a potential force of change, operating on a global scale and affecting many dimensions of society (Wilcove et al., 1998; Ohlemuller et al., 2006).

Tithonia diversifolia (Hemsly) A. Gray (Asteraceae), commonly called Mexican sunflower, is a common shrub (weed) native to Central America but has become naturalized in many tropical countries, including Nigeria. It is now widely distributed throughout the humid and subhumid tropics in Central and South America, Asia and Africa (Sonke, 1997), and it is common in indigenous fallow systems in Southeast Asia. *Tithonia* was probably introduced into Africa as an ornamental (Akobundu and Agyakwa, 1987). It has been reported to be present in Kenya (Niang et al., 1996), Malawi (Ganunga et al., 1998), Nigeria (Ayeni et al., 1997), Rwanda (Drechsel and Reck, 1998), Zimbabwe (Jiri and Waddington, 1998) and Zambia (Muoghalu and Chuba, 2005).

T. diversifolia is now prominent and fast-growing in Nigeria, inhabiting the rainbelt of the southern part of Nigeria, especially the southwestern and the coastal regions. It also inhabits the wet part of the Guinea savanna, especially along the fringes of the rain belt (latitude 6-9°N). States with infestation include Lagos, Ogun, Osun, Ekiti, Ondo, Edo, Imo, Anambra, Delta, Bayelsa, Rivers, Abia, Enugu, Ebonyi, Cross River, Benue, Kogi, Oyo, Kwara, Taraba (Agboola et al., 2005) and Plateau State.

T. diversifolia is an invasive, annual weed, growing aggressively along road path, abandoned farmlands and hedges all over Nigeria (Shokalu, 1997). It has been used successfully to improve soil fertility and crop yields in Kenya (Jama et al., 2000), Malawi (Ganunga et al., 1998), Nigeria (Ayeni et al., 1997), Rwanda (Drechsel and Reck, 1998) and Zimbabwe (Jiri and Waddington, 1998). It has also been found in Cameroon, Uganda and Zambia (Shokalu, 1997). It has different uses, such as ornamental plant, animal feed (Farinu et al., 1999; Olayemi, 2006), insecticide (Akanbi et al., 2007), nematicide and soil fertility improvement (Jama et al., 2000). Other reported uses of *Tithonia* include fodder (Anette, 1996; Roothaert and Patterson, 1997; Roothaert et al., 1997), poultry feed (Odunsi et al., 1996), fuelwood (Ng'inja et al., 1998), compost (Drechsel and Reck, 1998; Ng'inja et al., 1998), land demarcation (Ng'inja et al., 1998), soil erosion control (Ng'inja et al., 1998), building materials and shelter for poultry (Otuma et al., 1998). In addition, extracts from *Tithonia* plant parts reportedly protect crops from termites (Adoyo et al., 1997) and contain chemicals that inhibit plant growth (Baruah et al., 1994; Tongma et al., 1997), control insects (Carino and Rejestes, 1982; Dutta et al., 1993) and possess medicinal value for treatment of hepatitis (Lin et al., 1993; Kuo and Chen, 1997) and control of amoebic dysentery (Tona et al., 1998).

T. diversifolia propagates from seeds and vegetative growth (Muoghalu and Chuba, 2005). Seeds frequently germinate naturally under the tithonia canopy, and the seedlings can be dug up and transplanted elsewhere. When established from seeds in the field, germination can be poor if the seeds are sown deep or covered with clayey soil and covering the seeds with a thin layer of sandy soil and grass mulch can enhance germination (King'ara, 1998).

In Nigeria, most especially in the southwestern region, *T. diversifolia* had been identified to be invasive following its introduction and is fast spreading, displacing the native species and affecting the soil nutrient status. There has been paucity of studies on the impact of *T. diversifolia* on the species diversity, composition and soil nutrient status of the invaded vegetation. This study therefore investigated the impact of *T. diversifolia* on the soil, species diversity and composition of vegetation.

METHODOLOGY

Study area

This study was carried out in Ile-Ife in southwestern Nigeria. Ile-Ife lies within latitudes 07°30' N to 07°35' N and longitudes 04°30' E to 04°35' E. The original vegetation of Ile-Ife has been described as lowland forest zone (Keay, 1959), semi deciduous moist forests (Charter, 1969) and Guineo-Congolian forest drier type (White, 1983). Hall (1969) also described the vegetation as the dry forest sub-group Figure 1.

There are two prominent seasons in Ile-Ife area: a rainy and a dry season. The dry season is short, usually four months from November to March, and longer rainy season prevails during the remaining months. The weather report from the meteorological stations located within OAU Teaching and Research farm showed the annual rainfall at Ile-Ife averaged 1400 mm year^{-1} in a 5-year survey (Oke and Isichei, 1997) and mean annual temperature ranges from 22.5 to 31.4°C (Odiwe et al., 2012). The relative humidity in the early morning is generally high, usually over 90% throughout the year. At midday it is rather lower, around 80% in the wet season, as low as 50-60% in the dry season (Hall, 1969).

The geology of the area is underlain by the Precambrian basement complex of the southwestern Nigeria. The rock consists of banded gneisis and migmatite quartzites, quartz, mica, schists and related rocks (Smyth and Montgomery, 1962).

The soils of the area are moderately to strongly leached and have low to medium humus contents, weakly acidic to neutral surface layers and moderately to strongly acidic sub soils (Smyth and Montgomery, 1962). It is derived from materials of old basement complex which is made up of granitic, metamorphosed

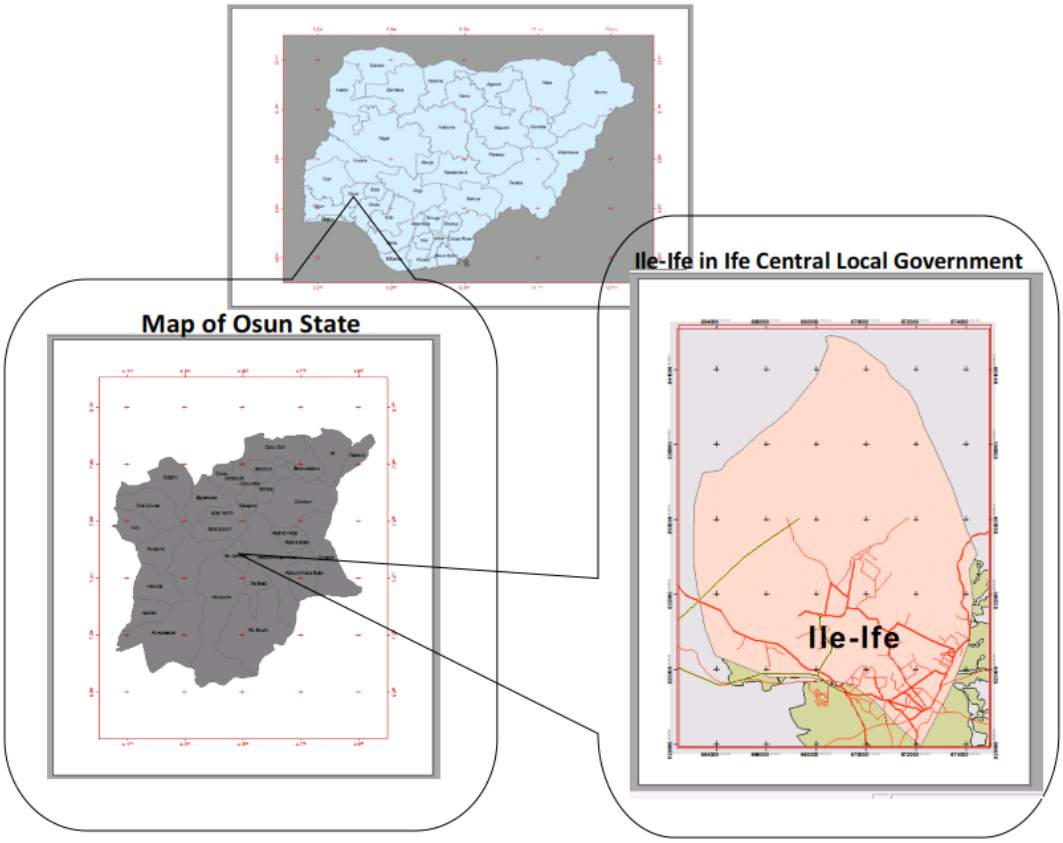

Figure 1. Location of Ile-Ife in Osun State, Nigeria.

sedimentary rock (Hall, 1969).

Vegetational analysis

An extensive search of sites heavily invaded by *T. diversifolia* in different locations at Ile-Ife was carried out. Ten of such sites were selected and sample plots established in them. In each location, a pair of 5 x 5 m adjacent sample plots was established. One plot of the pair was placed at *T. diversifolia* invaded vegetation (invaded plot) where *T. diversifolia* was dominant and has a high cover, and the second plot was allocated at neighboring vegetation, where the *T. diversifolia* has no cover (uninvaded plot). The uninvaded plot was chosen so as to have similar site conditions as possible to the invaded plot. The geographic locations of sample plots as determined by Geographic Positioning System (GPS) are shown in Table 1.

In each plot, all species of vascular plants were identified to the species level. Specimens of plant species that could not be identified in the field were collected, pressed and identified in the IFE Herbarium (IH). The species composition of the plots was established by listing the plant species encountered in each plot, summing up to get the total number of plant species for the plot. Authorities of botanical nomenclature follow the Flora of West Tropical Africa (Hutchinson and Dalziel, 1954-72).

Three 5-m line transects were randomly established in each plot. At every metre point along each transect, the cover of the plant species in the plot was taken. The number of 'hits' on each species was used to calculate the percentage cover of the species in the plot. Species cover was used as importance values for calculating the Shannon-Wiener diversity index (H') and evenness (J'). Evenness was calculated as H'/lnS, where S is the species richness expressed as the number of species. Differences in species richness, Shannon-Wiener index (H') and evenness (J') between invaded and uninvaded plots were used to measure the effect of invasion on these community characteristics.

The Shannon diversity index (H') was used to characterize species diversity in each plot using the formula.

To assess the impact of invasion on species composition of resident species, Sorensen index of similarity (ISs) between each plot pair was calculated based on species presence.

In addition, for each invasive species studied, the total number of species recorded in all plots with invaded and uninvaded vegetation (Stotal) was used as a measure of the impact of the invasion on species richness S. This was expressed as the percentage reduction of the total number of species recorded in invaded (S_{tot} inv) plots as compared to that recorded in uninvaded plots (S_{tot} uninv = 100%). Positive and negative values indicate a higher species number in uninvaded and invaded vegetation, respectively.

Soil analysis

Five soil samples each were randomly collected to a depth of 0-15 cm from invaded and uninvaded plots using a soil auger. The five samples were bulked for each plot, air-dried and sieved through <2 mm mesh size for chemical analysis. The soil samples were analysed for soil pH, exchangeable cations (Ca, Mg, K and Na), total nitrogen, available phosphorus and organic matter. Soil pH was determined in 0.01 M $CaCl_2$ (1:2 soil solution ratio) using a glass

Table 1. GPS locations of invaded and uninvaded sites for *T. diversifolia*.

Site	*Tithonia diversifolia*	
	Invaded	**Uninvaded**
1	N07° 30.380, E004° 32.706	N07° 30.391, E004° 32.704
2	N07° 30.156, E004° 33.265	N07° 30.164, E004° 33.718
3	N07° 31.889, E004° 34.966	N07° 31.895, E004° 34.962
4	N07° 30.725, E004° 31.062	N07° 30.707, E004° 31.045
5	N07° 32.153, E004° 32.217	N07° 32.141, E004° 32.200
6	N07° 32.131, E004° 32.210	N07° 32.139, E004° 32.216
7	N07° 31.308, E004° 33.295	N07° 31.322, E004° 33.278
8	N07° 31.088, E004° 32.553	N07° 31.101, E004° 32.545
9	N07° 32.147, E004° 32.381	N07° 32.138, E004° 32.375
10	N07° 33.421, E004° 31.805	N07° 33.417, E004° 31.796

Table 2. Impact of *T. diversifolia* on community characteristics of invaded sites.

Parameter	Uninvaded	Invaded	decrease over uninvaded (Impact) (%)
Total species	59	44	(-)25.4
Total number of families	25	24	(-)4.0
Shannon's index of diversity (H')	2.9836	2.1787	(-)27.0
Index of evenness (J')	0.8036	0.6035	(-)24.9
Similarity index		32.6%	
Dissimilarity index		67.4%	

electrode pH meter (Pye model 292). Total nitrogen, available phosphorus and exchangeable cations (Ca, Mg, K, Na) analyses were done according to the method of International Institute of Tropical Agriculture (IITA) Manual Series No 7 (Tel and Rao, 1982). The soil organic matter was determined using Walkey–Black method (Black, 1965). The plant samples collected from both invaded and uninvaded plots were analysed for nitrogen, phos-phorus, potassium, calcium, magnesium and sulphur according to the method of International Institute of Tropical Agriculture (IITA) Manual Series No 7 (Tel and Rao, 1982).

Statistical analysis

For each experiment, statistical analysis was done using software programmes like SPSS ver. 10.0. For determining the significance of a single treatment with control (paired treatment), ANOVA was applied. Significance of difference between soil characteristics of control and weed invaded sites was determined using one way ANOVA at $P \leq 0.05$.

RESULTS

Impact of *T. diversifolia* invasion on the structure of invaded communities

The invasion of *Tithonia diversifolia* drastically reduced the species composition of the invaded communities by 25.4%, from 59 species in the uninvaded area to 44 species in the invaded area (Table 1). The similarity index of the communities in the invaded and uninvaded areas was only 32.6% (Table 1), which shows a clear indication of loss of species due to the invasion of *T. diversifolia*. The Shannon-Wiener diversity of the *T. diversifolia* for uninvaded sites was 2.984 while it was 2.179 in the invaded sites. This is a reduction of 27.0% in species diversity as a result of invasion (Table 2).

Species evenness (J') was significantly decreased from 0.8036 in uninvaded to 0.6035 in invaded communities (24.9% reduction) due to the invasion of *T. diversifolia* (Table 2).

Impact of *T. diversifolia* invasion on species composition of invaded communities

Tithonia invasion heavily disturbs the composition and structure of species in the invaded habitats. In the present study, floristic composition between *Tithonia* invaded and uninvaded areas was compared. There were 34 families observed in *T. diversifolia* invaded and uninvaded sites with Fabaceae having the highest number (9) of species. Twenty-five of these families were present in uninvaded plots and 24 in invaded plots. Fifteen families were common to the plots while 19 families were present in only one plot.

The list of families encountered in both invaded and uninvaded plots for *Ti. diversifolia* are Malvaceae, Araceae, Amaranthaceae, Fabaceae, Euphorbiaceae,

Sapindaceae, Poaceae, Acanthaceae, Combretaceae, Cucurbitaceae, Apocynaceae, Icacinaceae, Piperaceae, Celastraceae and Sterculiaceae Table 3.

Impact on soil nutrients

The soil pH of invaded sites was significantly higher than that of uninvaded sites ($F = 39.421$, $P \leq 0.05$) (Table 4). It was slightly alkaline in the invaded sites (Table 4).

The soil nitrogen concentrations of the *T. diversifolia* invaded sites were significantly higher than that of the uninvaded sites ($F=53.513$, $P \leq 0.05$) (Table 4). The concentrations of all the other soil properties (organic carbon, calcium, magnesium, potassium, sodium and phosphorus) in the invaded sites by the invasive species were significantly higher than those of the uninvaded sites (*T. diversifolia* invaded sites: organic carbon, $F= 51.60$, $P \leq 0.05$; Ca, $F= 56.85$, $P \leq 0.05$; Mg, $F= 39.451$, $P \leq 0.05$; K, $F= 16.91$, $P \leq 0.05$; Na, $F= 26.47$, $P \leq 0.05$; P, $F= 13.82$, $P \leq 0.05$). There were no significant differences in the soil concentrations of these elements in *T. diversifolia* invaded sites (Table 4). However, while the soil pH and the concentrations of nitrogen, magnesium, potassium and sodium in invaded sites were not significantly different, their carbon ($F= 60.615$, $P \leq 0.05$), calcium ($F= 53.682$, $P \leq 0.05$) and phosphorus ($F= 9.515$, $P \leq 0.05$) were significantly different (Table 4).

Percent organic carbon in the invaded sites was increased bt nearly 27.1% by *T. diversifolia* and the increase in the available nitrogen content by *T. diversifolia* invasion (39.45%) was highest among all other nutrients. The soil available phosphorus, potassium and sodium concentrations were increased by 18.54, 37.05 and 35.25% by *T. diversifolia* invasion when compared with those of uninvaded sites. Similarly, the soil concentrations of available calcium and magnesium were increased by 38.11 and 25.6% respectively in the *T. diversifolia* invaded soil.

DISCUSSION

Being primary producers, the plants are the major components of the ecosystem. So, it is very important to save the plant kingdom from various threats to sustain all other living beings. The higher loss in the case of the plants growing in invaded areas shows that they become less productive in comparison with the plants in the control area. The pressure created by the invasive species in the invaded habitats disturbs the functions of biological communities and reduce the diversity of species and dependent fauna (Kinzig et al., 2001). To respond effectively to the invasive species problems, quantitative measurements of the impact of invasion on diversity are required (Schooler et al., 2006).

T. diversifolia has become a very strong invader in south western part of Nigeria and it has increased its density and abundance in the invaded habitats as a result posing a threat to the extinction of native species. An increasing abundance of the invaders can decrease the diversity of species (Kercher and Zedler, 2004). Much effort has been put into identifying determinants constraining broad-scale variability in species richness (Francis and Currie, 2003; Rahbek, 2005). It is apparent that the factors influencing patterns of species richness vary with the geographical extent and sample resolution (Willis and Whittaker, 2002). Therefore, only by multiple analyses scales for different locations and at various spatial scales, general explanations of broadscale species richness, diversity and distribution patterns can be derived (Zhao and Fang, 2006).

It is concluded from the studies that *T. diversifolia* is a strong invader in these areas and its increased abundance, cover and density poses a threat to the native species which also include medicinally important species. The decrease in ecological indices (Shannon Weinner diversity, abundant species, index of evenness etc.) in the *T. diversifolia* invaded habitats clearly signifies that these become less productive and stable as compared to non-invaded habitats. There were some species which were totally lost in the invaded areas while some other species preferred to grow there. The absence of seedlings of tree species like *Vigna gracilis*, *Euphorbia hirta, Indigofera trifoliate*, *Icacinea trichanta* and *Milletia thonningi* in the invaded areas showed that it inhibited their seedling growth. Thus, *T. diversifolia* directly alters the growth of other plant species by forming its own monocultures.

The invasion of *T. diversifolia* also alters the physico-chemical properties of soils in the invaded areas. The soils in the invaded areas become nutrient rich which generally help in the growth of invasive species. It was clear from the results that the values of all soil nutrients were found to be higher in the *Tithonia* invaded areas as compared to the control. Minimum change was observed in the case of pH as compared to other parameters. Likewise, the phenolics well known groups of allelochemical were found to be more in weed-invaded soil as compared to the control soil. These phenolics are released from the plant part through various mechanisms such as leachation from above ground parts, root exudation, volatilization or microbial degradation. These allelochemicals besides imparting the plant allelopathic property also regulate the biotic communities of soil and alter the phy-sical and chemical properties of soil (Nardi et al., 2000). Many studies suggest that allelopathy may contribute to the ability of particular alien species to become dominant in the native plant communities (Abdul-Wahab and Rice, 1967; Vaughn and Berhow, 1999; Ridenour and Callaway, 2001). Several aggressive weeds exhibit the phenomenon of allelopathy as a mechanism of interference which provides them competitive advantage over other plants. El-Ghareeb (1991) studied the allelopathic effect of the invasive plant *Tribulus terrestris* on surrounding vegetation in an abandoned field of Kuwait. His study demonstrated that besides the growth inhibitory effect of plant on other plants, the soil moisture and concentration

Table 3. Species composition of *T. diversifolia* invaded and uninvaded plant communities in Ile-Ife, Southwest Nigeria.

Plant species	Family	Uninvaded	Invaded
Abutilon sp.	Malvaceae	-	+
Anchomanes difformis	Araceae	-	+
Achyranthes aspera	Amaranthaceae	+	-
Aeschynomene indica	Fabaceae	+	+
Albizia angertifolia	Fabaceae	+	-
Albizia zygia	Fabaceae	+	+
Alchornea laxiflora	Euphorbiaceae	+	+
Allophylus africanus	Sapindaceae	+	-
Alternanthera sessilis	Amaranthaceae	+	-
Andropogon gayanus	Poaceae	+	-
Aneileme beninse	Commelinaceae	-	+
Aspilia africana	Asteraceae	-	+
Asystasia gangentica	Acanthaceae	-	+
Blighia unijugata	Sapindaceae	+	-
Bridelia micrantha	Euphorbiaceae	+	-
Calopogonium mucunoides	Fabaceae	+	+
Chasmanthera dependens	Menispermaceae	+	-
Chassalia kolly	Rubiaceae	-	+
Chromolaena odorata	Asteraceae	-	+
Cissus argueta Hook. f.	Vitaceae	-	+
Combretum nigerica	Combretaceae	+	+
Cnestis ferruginea	Connaraceae	-	+
Croton bonplandianum	Euphorbiaceae	+	+
Croton zambesicus Muell. Arg.	Euphorbiaceae	-	+
Cucurbita sp	Cucurbitaceae	+	-
Culcasia scandens	Araceae	+	-
Cynodon dactylon (L.) Pers	Poaceae	+	+
Cyathula prostate	Amaranthaceae	+	+
Deinbolia pinnata	Sapindaceae	-	+
Desmodium gangeticum	Fabaceae	+	+
Digitaria sp.	Poaceae	+	-
Dioscorea dumetorum (Kunth) Pax	Dioscoreaceae	+	-
Euphorbia heterophylla	Euphorbiaceae	+	+
Euphorbia hirta	Euphorbiaceae	+	-
Ficus exasperate	Moraceae	-	+
Gloriosa superb	Liliaceae	+	-
Glyphaea brevis	Tiliaceae	+	-
Holarrhena floribunda	Apocynaceae	-	+
Icacina trichantha	Icacinaceae	+	-
Indigofera trifoliate	Fabaceae	+	-
Ipomoea carnea	Convolvulaceae	+	-
Jateorhiza macrantha	Menispermaceae	+	-
Justicia insularis	Acanthaceae	+	-
Luffa cylindrical	Cucurbitaceae	-	+
Mallothus oppositifolius	Euphorbiaceae	-	+
Margaritaria discoidea (Baill.)	Euphorbiaceae	+	-
Mariscus alternifolius Vahl	Cyperaceae	+	-
Merremia sp.	Convolvulaceae	+	-
Mezoneuron benthamianum	Leguminosae	+	-
Millettia thonningii	Fabaceae	+	-

Table 3. Contd.

Mimosa pudica	Fabaceae	+	+
Mondia whitei	Apocynaceae	+	-
Mormodica charantia	Cucurbitaceae	-	+
Mucana pruriens	Fabaceae	+	-
Newbouldea laevis	Apocynaceae	+	-
Panicum maximum	Poaceae	+	-
Paulina pinnata	Sapindaceae	-	+
Pouzolzia guineensis	Urticaceae	+	-
Pennisetum purpureum	Poaceae	+	+
Pepperonea pellucida	Piperaceae	+	+
Phyalopsis sp.	Acanthaceae	+	-
Pleiuserae barterii	Apocynaceae	+	-
Pyrennicantra stanthia	Icacinaceae	-	+
Rottboellia exaltata	Poaceae	-	+
Rotbollia cochinchinensis	Poaceae	+	-
Salacia chinensis	Celastraceae	+	-
Salacia pallens	Celastraceae	+	+
Securinega virosa	Euphorbiaceae	+	+
Senna hirsute	Fabaceae	+	-
Sida acuta	Malvaceae	+	+
Sida corymbosa	Malvaceae	-	+
Sida veronicifolia	Malvaceae	-	+
Smilax kraussiana	Smilacaceae	-	+
Spigelia althelmia	Loganiaceae	-	+
Spondias mombin	Anacardiaceae	+	-
Sporobolus pyramidalis	Poaceae	+	-
Stachytapheta angustifolia	Verbenaceae	+	-
Sterculia tragacantha	Sterculiaceae	+	-
Synedrella nodiflora	Asteraceae	+	+
Talinum triangulare	Portulacaceae	-	+
Tithonia diversifolia	Asteraceae	-	+
Tridax procumbens	Asteraceae	+	+
Urena lobata	Malvaceae	+	-
Vigna gracilis	Fabaceae	+	-
Voacanga africana	Apocynaceae	-	+
Total		**59**	**44**

of N, P and K were significantly higher in *T*. *terrestris* site. In the pre-sent study too, the amounts of available nutrients were significantly more in weed-invaded soils as compared to the weed free soils. Abundant evidences support the idea that higher resource availability increases the suscepti-bility to invasion of plant communities (Burke and Grim, 1996; Maron and Connor, 1996).

Further, the absorption of phenolics, the allelopathic compounds, by soil particles and their microbial break-down may account for the outcome of the present obser-vations (Dalton, 1999; Huang et al., 1999; Wardle et al., 1998) which are further affected by various soil factors such as soil texture, organic carbon and organic matter etc. (Kobayashi, 2004).

The reason why some invasive plants are so success-ful in new environments may be that they bring novel mechanisms of interactions with the recipient community. However, Dietz et al. (1996) concluded that factors other than allelopathy might be operating in nature that favours

Table 4. Soil pH and nutrient elements concentrations in the invaded and uninvaded sites of *T. diversifolia*.

Soil properties	*Tithonia diversifolia*	
	Invaded site	**Uninvaded site**
pH	7.44±0.22[b]	5.4233±0.1197[a]
Nitrogen	2.999±0.866[b]	1.816±0.080[a]
Organic Carbon	0.70253±0.023[c]	0.4759±0.02054[b]
Calcium	2.9994±0.1033[c]	1.8564±0.1109[b]
Magnesium	0.834±0.0274[b]	0.6205±0.0201[a]
Potassium	0.2556±0.0169[b]	0.1609±0.0155[a]
Sodium	0.4059±0.0212[b]	0.2628±0.0179[a]
Phosphorus	64.0621±2.5112[c]	52.1855±2.0577[a]

*Values are mean ± 95% confidence interval; ** Values with the same superscript along the same row are not significant different .

rapid establishment and persistence of dense stands of alien species.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Endemic plant species composition and their status in Boda Dry Evergreen Montane Forest, West Showa, Ethiopia

Fikadu Erenso* and Melesse Maryo

Department of Biology, College of Natural and Computational Science, Dilla University, P.O Box 419, Ethiopia.

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The present study was aimed to show the species compositions and their status in Boda forest Oromia Regional State, West Ethiopia. Systematic sampling method was used to collected vegetation data from 60 plots of 20 x 20 m (400 m^2) quadrats laid at every 50 m along five transect lines from south-north direction was employed for the analysis of woody species using compass and subplots of 1 x 1 m at the four corners and the center of the large quadrat was used for herbaceous plants. A total of 133 species of plants (herbs, shrubs, lianas and trees) were recorded. Out of these, 11 plant species were endemic which have been included in the preliminary list assessed for IUCN Red Data List, of which 1 species is nearly threatened, one species is vulnerable, and the other nine of them are at the status least concern. To provide a better management and monitoring as well as to maintain the biodiversity, cultural and economic values of the forest unsustainable used would be controlled by implementing various conservation activities in place.

Key words: Dry evergreen montane forest, endemic species, Boda forest.

INTRODUCTION

Tropical forests are the storehouses of biodiversity and constitute the most diverse plant communities on earth (Supriya and Yadava, 2006). According to Wilson (1988), over half of the global number of species, which is estimated to be in millions, is found to be in tropical forests. Tropical forests account for 52% of the total forest area of the world, of which 42% is dry forest, 33% is moist forest and 25% is wet and rainforest (Murphy and Lugo, 1986). The largest proportion of tropical dry forests is found in Africa, where it accounts for 70-80% of the forested area (Demel, 1996) and Africa's rich biodiversity is estimated to comprise about 25% of global biodiversity in terms of ecosystems, species composition and genetic variety (MOA, 1998). According to Cotzee (1978), the East African Mountains have the richest and most diversified tree flora. The Ethiopian highlands contribute to more than 50% of the land area with Afromontane vegetation of which dry montane forests form the largest part (Tamirat, 1994).

Ethiopia has also several major ecological systems that support large and highly varied genetic resources along with its extremely variable agro-climatic conditions. The

*Corresponding author. E-mail: fikaduerenso@gmail.com.

country has a great topographical diversity with high, rugged mountains, flat topped plateaus, deep gorges, incised river valleys and rolling plains. The altitudinal variation ranges from 110 m below sea level in some areas of Kobar Sink, to 4,620 m a.s.l. at Ras Dejen [Dashen] (FAO, 1996). The country also consists of two major high plateau regions separated by the Rift Valley and bounded on all sides by lowlands (Friis 1992; Tamrat, 1993). The diversity of Ethiopia's terrain determines regional variations in climate, natural vegetation, soil composition and settlement patterns. These diverse topographic features and climatic conditions of the country have led to the emergence of habitats that are suitable for the evolution and survival of various plant and animal species (EWNHS, 1996). The size of Ethiopian flora is estimated to be over 6500-7000 species of vascular plants, of which about 12% are considered endemic (Tewolde, 1991). Endemism is high on the plateau, mountains, in the Ogaden and Borana and Bale lowlands (Vivero et al., 2006; Girma, 2008).

According to Fikadu et al. (2014) as cited from Ensermu et al. (1992), 120 threatened endemic plant species are known from Ethiopia. Thirty five of these species were from the Dry Afromontane forests of the country. Dry evergreen montane forest has a very complex type of vegetation, roughly above 1500 m a.s.l. and below 3200 m a.s.l., with an average annual temperature and rainfall of 14-25°C and 700-1100 mm, respectively (Friis, 1992; Zerihun, 1999). Boda dry evergreen montane forest is one of the remnant dry afromontane forests that are found in the high lands of West Showa next to Chilimo National priority forest. Settlements, illegal cutting, small patches of farmland, substitution by the exotic species and open pasture fields are challenges that are facing this forest. Overgrazing and continuous human interference are believed to lead to an irreversible change in the function of forests (Badege, 2001). These frequently lead to loss of forest cover and biodiversity, erosion, desertification and reduced water resources (Ensermu and Teshome, 2008). Indigenous knowledge on medicinal and other useful plants is also eroded with destruction of these forests (Kitessa and Tsegaye, 2008). Therefore, this study was aimed to assess the diversity of endemic plant species and their status in Boda forest. The information gathered is supposed to be important for further studies and conservation measure.

MATERIALS AND METHODS

The study area

The study area, Dendi district, is one of the eighteen districts of the West Showa zone of Oromia Regional State. The district capital city, Ginchi, is located 77 km west of Addis Ababa, on the Addis Ababa-Naqamte Road. Geographically, the district lies within the coordinates of 8°43'N-9°17' N and 37°47'E-38°20' E. The district covers about a total area of 104,680 ha. Of which, 72,836 ha is covered by farm land, 19,080 ha grazing-land, 9,685 ha forest and shrubs and others 3,079 ha with the population of 192,784 (99,475 males and 93309 females). The district has 48 peasant associations and 5 urban out of which Ghinchi and Olankomi have municipal governments (Fikadu et al., 2014).

Boda Natural forest is at Boda Bosoka Peasant associations, 22 km away from the district's capital city, close to the main road running Ginchi-Busa town. It got its name from the town found nearby called Boda. Sometimes it is called "Renda Beteskane" Because of the Orthodox Church found at the tip of the mountain of the forest. It covers around 20 ha.

The physiographic region of the district is characterized by one major escarpment running from east to west direction. The steepness of the escarpment varies from place to place being generally steeper at the central part of the district. Both on the top and bottom, the escarpment merges with flat lands largely used for farming. The altitudinal range of the district is between 2,000 and 3,288 m a.s.l. Besides, the relief feature of the area is characterized by rugged topography, which provides a variety of hills having interesting scenes. The district is an important watershed area for Awash and Nile river basin (Tamrat, 1994).

Dendi district has some natural endowments to attract scientists and researchers:

1. The importance of the Chilimo Natural Forest at country level;
2. The topography and the soil type that the district stretches from 2,000 to 3,288 m above sea level;
3. The existence of Lake Dendi, from where the district got its name, is a unique lake found at highland in the shape of an "8" and encircled by a chain of mountains. Recently, the attempts by ALMOEZ Holding Group, a Qatari-Egyptian Investment Company (dendilake.com) that intruded into the area with "investment card", and the US, NASA that posted the Dendi report have made the area popular these days. Only a few years ago, the lake area was an inaccessible area where nobody was interested to go, because of the ragged landscape.
4. Cave of Gifo and Cave of Aba Ife, with no investigation done on them. Although, both of them found at attractive physical form of landscape and each of them have many classes at inside and many openings (Plate 1).

Vegetation and environmental data

The vegetation data were collected systematically from 60 plots of 20 x 20 m (400 m^2) quadrats laid at every 50 m along 5 transect lines from south-north direction using compass following the Braun-Blanquet approach of phytosociology as modified by vander Maarel (1979). Sub plots of 1 x 1 m at four corners and the center of the large quagrat was used for herbaceous plants. The distance between each transect line was 100 m in a zigzag form of starting point of laying plot. This is to include as much vegetation as possible that can represent the vegetation of the study area. Additional plant species occurring outside the quadrats, but inside the forest within 10 m distance was also recorded only as 'present' for floristic composition, but they were not used in the subsequent vegetation data analysis (Tamrat, 1994). The vernacular (local) names were used when available. Plant species in each plot was counted and recorded at individual level, and voucher specimens was also collected, numbered, pressed and taken to the National Herbarium of Ethiopia (ETH), Addis Ababa University, for identification and storage following standard taxonomic method (Bridson and Forman, 1992).

RESULTS

The richness of plant species in Boda Forest

A total of 133 specimens of plants (herbs, shrubs, trees,

Plate 1. Cave of Gifo and Cave of Aba Ife (Photo by Fikadu, September, 2013 G.C).

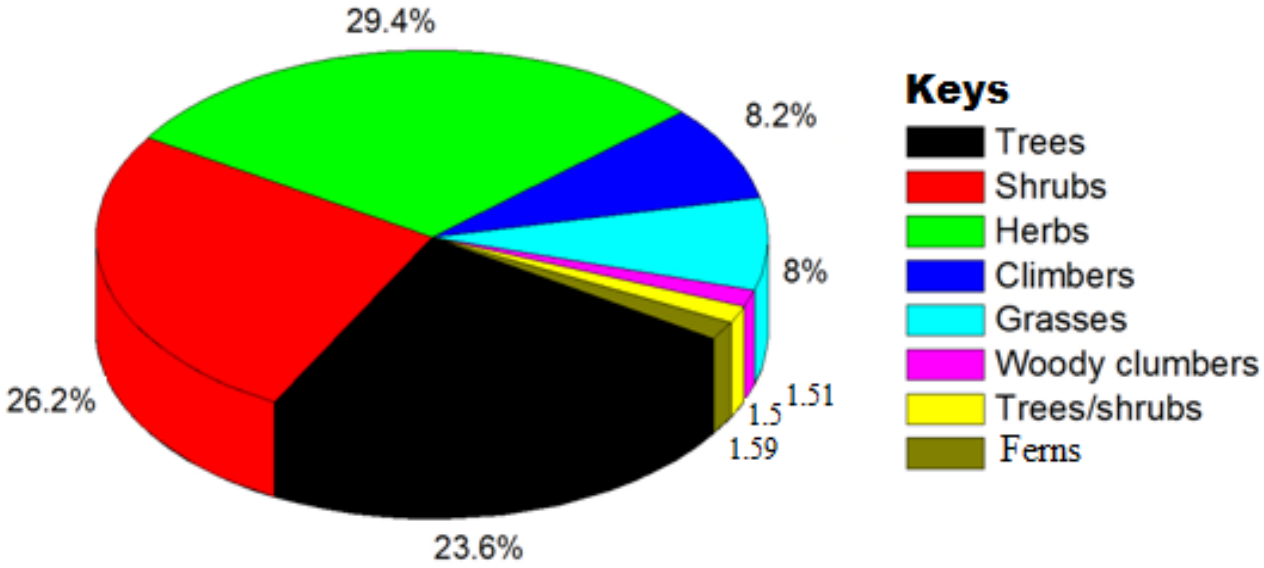

Figure 1. Habit of plants in the study forest.

shrubs/trees, climbers and tree/climbers) were identified and documented from the Boda forest. The identified species belong to 114 genera and 62 families. Two species, *Geranium arabicum* and *Opuntia ficus indica* were collected outside the sampling plot. The collected species were composed of 23.6% trees, 26.2% shrubs, 29.4% herb, 1.5% trees/shrubs, 8.2% climbers, 8% grass, 1.51% woody climbers, 1.5% tree/shrubs, and 1.59% fern (Figure 1).

Table 1 below indicates the number of Families, Genera and species of woody species in Boda Forest. The major families were Fabaceae represented by 14 spp.

Table 1. The number of families, genera and species of plants in Boda Forest

Family	Genera	species	Percentage	Family	Genera	species	Percentage
Acanthaceae	2	3	2.70	Myrsinaceae	2	3	2.70
Acacardiaceae	1	1	0.90	Myrtaceae	1	1	0.90
Adiantaceae	1	1	0.90	Oleaceae	2	2	2.00
Anacardiaceae	1	1	0.90	Orchidaceae	1	1	0.90
Apocynaceae	1	1	0.90	Papilionaceae	1	1	0.90
Araceae	1	1	0.90	Phytolaccaceae	1	1	0.90
Asclepiadaceae	2	3	2.70	Piperaceae	1	1	0.90
Asparagaceae	1	1	0.90	Pittosporaceae	1	1	0.90
Asteraceae	9	12	10.90	Plantaginaceae	1	1	0.90
Balsaminaceae	1	1	0.90	Poaceae	6	9	8.18
Boraginaceae	1	1	0.90	Podocarpaceae	1	1	0.90
Celastraceae	1	2	2.00	Polygalaceae	1	1	0.90
Commelinaceae	2	2	2.00	Polygonaceae	2	2	2.00
Crassulaceae	1	1	0.90	Pteridaceae	1	1	0.90
Cucurbitaceae	1	1	0.90	Ranunculaceae	1	1	0.90
Cupressaceae	2	2	2.00	Rhamnaceae	1	2	2.00
Cyperaceae	2	2	2.00	Rosaceae	3	4	3.63
Ebenaceae	1	1	0.90	Rubiaceae	5	6	5.00
Ericaceae	1	1	0.90	Rununculaceae	1	1	0.90
Euphorbiaceae	3	5	4.50	Rutaceae	2	2	2.00
Fabaceae	12	14	12.70	Salicaceae	1	1	0.90
Flacourtiaceae	2	2	2.00	Santalaceae	1	1	0.90
Geraniaceae	1	1	0.90	Sapotaceae	1	1	0.90
Guttiferaeceae	1	2	2.00	Scrophulariaceae	1	1	0.90
Iridaceae	1	1	0.90	Solanaceae	2	4	3.63
Lamiaceae	6	6	5.50	Thelypteridaceae	1	1	0.90
Loranthaceae	1	1	0.90	Tiliaceae	1	1	0.90
Malvaceae	3	3	2.70	Urticaceae	2	2	2.00
Meliaceae	1	1	0.90	Usnaceae	1	1	0.90
Menispermaceae	1	1	0.90	Verbanaceae	1	1	0.90
Moraceae	1	1	0.90	Vitaceae	1	1	0.90
Total				62	114	133	100

(12.7%), Asteraceae by 12 species (10.9%), Poaceae by 9 species (8.18%), Lamiaceae and Rubiaceae each with 6 species (5% each), Euphorbiaceae by five species (4.5%), Solanaceae and Rosaceae, by 4 species (3.63 each), Acanthacerae, Asclepiadaceae, Malvaceae, and Myrsinaceae are represented by 3 species (2.7% each), Celastraceae, Commelinaceae, Cupressaceae, Cyperaceae, Flacourtiaceae, Guttiferaeceae, Oleaceae, Polygonaceae, Rhamnaceae, Rutaceae and Urticaceae are represented by 2 species (2% each) of the total floristic composition. The remaining (38%) families were represented by one species only.

Out of the plants identified in this study area, 11 (8.4%) were endemic plant species which are included in the preliminarily assessed list for IUCN Red Data List, of these 1 species is nearly threatened (*Maytenus addat* (Loes.) Sebsebe), and 1 species is vulnerable (*Echinops kebericho* Mesfin) the other 9 of them are least concern (Table 2). From the endemic species that were recorded in IUCN Red List in the study area herbs, shrubs, trees and climbers constitute 45, 27, 18 and 9%, respectively.

DISCUSSION

Species diversity and endemism

Ethiopia possesses a large natural and cultural diversity with a wide range of climates which results from its topography and latitudinal location. The great plains of Ethiopia occur at top two massive highland plateaus, divided into unequal halves by the Great Rift Valley. From the very hot arid and semi-arid lands in the east, the lowlands bordering the Sudan in the west and Dalol in the

Table 2. Endemic species of the study area, their IUCN Red List categories and distributions (Ha = Habit, T = tree, Sh = shrub, H = herb, C = climber, NT= nearly threatened, LC= least concern, VU= vulnerable).

Scientific name	Family	Ha	IUCN Red List Category
Bidens ghedoensis Mesfin	Asteraceae	H	LC
Clematis longicauda Steud. ex A. Rich.	Runnunculaceae	C	LC
Echinops kebericho Mesfin	Asteraceae	H	VU
Erithrina brueci Schweinf	Fabaceae	T	LC
Impatiens rothii Hook.f.	Balsaminaceae	H	LC
*Kalanchoe petitiana*A.Rich.	Crassulaceae	H	LC
Maytenus addat (Loes.) Sebsebe	Celestraceae	T	NT
Solanum giganteum Jacq.	Asteraceae	Sh	LC
Solanum marginatum L.f.	Solanaceae	Sh	LC
Urtica simensis Steudel	Urticaceae	H	LC
Lippia adoensis Hochst. ex Walp.	Verbanaceae	H	LC

north, where Africa crashes into Arabia, the land rising through semi-arid lowlands and pockets of tropical jungle, montane forests, and reaching afroalpine pastures on the slopes such as the Semien and Bale mountain ranges. Many of these mountain ranges reach over 4000 m asl, and are home to numerous endemic species of flora. There is a great disparity in altitude ranging from 116 m below sea level in Dalol to 4620 m asl in Semien (IBC, 2009). The variations in elevation and latitude have resulted in a wide difference in climates, which along with differences in soils form the basis for the wide plant diversity of the country. As a result, Ethiopia becomes a center of biological diversity with sizeable endemism, especially about 12% of the flora (Tewolde Berhan Gebre Egziabher, 1991). But the current studied afromontane forest belongs to the western massive highland plateaus where 131 plant species were recorded, of which 8.4% of the studied vegetation becomes endemic to the studied afromontane forest. The Ethiopian Flora is estimated to consist of between six and seven thousand species distributed in about 245 plant families (Tadesse and Mesfin, 2010). This biodiversity is of vital importance in the socio-economic, cultural and political life of the people. The highlands of Ethiopia, together with the highlands of East Africa, constitute the Afromontane floristic region (White, 1978). Though the Ethiopian highlands are the most extensive of the African mountainous regions, the number of species in them is lower than in the less extensive East African Mountains. This is probably because the Ethiopian highlands are, on the whole, drier than their East African counterparts (Tewolde Berhan Gebre Egziabher, 1991). However, the implicit belief that has existed hitherto, that the Ethiopian flora is rich both in species numbers and in endemics is, therefore, valid.

Loss of forest plant diversity

With escalating demographic pressure on diminishing natural resources, plant biodiversity is still being cleared at an alarming rate to open up land for agriculture and livestock production (Vivero et al., 2005). From the present study, *Echinops kebericho* has been registered under national red list as vulnerable for it is considered to be facing a high risk of extinction in the wild, mainly associated with its traditional medicinal use. Currently, medicinal plants are under threat in Ethiopia largely due to anthropogenic factors (Demisse, 2001; Giday et al., 2007; Birhane et al., 2011), environmental degradation, change in the peoples' lifestyles (Edwards, 2001; Hunde et al., 2006), agricultural expansion, deforestation and over harvesting of species (Kelbessa et al., 1992).

The genus *Echinops* is composed of about 12 species inhabiting usually degraded and dry land in Ethiopia. It is commonly referred to as "globe thistle" in Europe because of the spherical arrangement of the flowers. *Echinops kebericho* Mesfin, in depth and reported "… copious amounts of sesquiterpenes (10%) of which the dehydrocostus lactone is the major constituent." The roots and flower heads (capitula) of four species of *Echinops* are used in the treatment of headache and hemorrhoids by traditional people. One species, *E. kebericho* Mesfin, has been used as a fumigant, particularly after child birth, and as a medicinal plant to treat leprosy for centuries. The large tuberous roots are sold either cut up as small pieces or in whole in many open markets in Shewa, Gojjam and Wellega regions in Ethiopia (Tadesse and Mesfin, 2010). A study of Borana pastoralists in southern Ethiopia described the purpose (hygienic and perfumery), facilities used and processes associated with traditional fumigation techniques (Gemedo *et al.*, 2005). Fumigation using *E. kebericho* is particularly important after child birth in large areas of rural Ethiopia and it may be utilized in much the same way as in the Borana region. Furthermore, *E. kebericho* has been traditionally reported to have abortifacient action, and also used to treat epilepsy, epistaxis, atrophy, and sudden and devil sickness by people of Kembatta,

Southern Ethiopia (Melesse Maryo, 2013). Thus, due to its overuse in the wild the species is facing a high risk of extinction in the wild.

Similarly, *Juniperus procera*, *Podocarpus falcatus* and *Hagenia abyssinica* are tree species of dry evergreen montane forests of Ethiopia, which are dominant trees of the current study forest. They harbor the aforementioned endemic plant species but are currently facing big anthropogenic impacts. In Ethiopian Constitution, the State is the legal owner of the natural forests and woodlands of the country (FDRE, 1995). However, the State has failed to put in place organizations that give proper support to the forestry sector. The lack of effective institutions and the weak law enforcement means the forests and woodlands of the country remain open to all forms of exploitation. People access forests for timber, firewood, charcoal, other construction material, as well as forest grazing and browsing because there is no regulatory system or overseeing body over the harvesting of the products or other uses. This has resulted in the continuous and uncontrolled illegal logging that skims off selected valuable timber species, such as *Hagenia abyssinica, Afrocarpus* (*Podocarpus*) *falcatus* and a few others (Edwards, 2010). This in turn brings decline in the productivity and regenerative capacity such dominant and valuable tree species as well as the rich diversity of endemic plant species harbored within them.

Podocarpus falcatus and *Hagenia abyssinica* are two enormously important tree species in Ethiopia, both economically and ecologically. *H. abyssinica* is important as a source of medicine and also timber. *P. falcatus* yields a precious timber and is a source of food (fruits) and shelter for many birds and wild animals. A Global Trees Campaign project undertaken in 2000 studied the germination and propagation of the two species for ecological restoration. In July 2004, a Centre for Indigenous Trees Propagation and Biodiversity Development was established at area located some 50 km west of Addis Ababa, with a view to conserve *H. abyssinica, P. falcatus* and many other endangered Ethiopian trees. It was aimed to fight against plant biodiversity loss at the genetic, species and ecosystem levels, and to increase the capacity to provide practical solutions to conservation problems (Vivero et al., 2005). However, the condition seems improving in the current study at least in forest patches situated away from the urban centre. It was examined that the second most important timber tree species, *Juniperus procera* is regenerating at alarming rate, while *Podocarpus falcatus* also shows encouraging recovery.

Therefore, such good practices need to be further strengthened to save many valuable forest plant diversity in the country.

Conclusion and recommendations

Boda Forest is one of the remaining Afromontane forests harboring many endemic species. This forest is ecologically, socially, economically and culturally very important for the inhabitants residing nearby who are mostly dependent on forest products to make their living. Loss of such a forest including the various threatened species would have negative impact on the environment, biodiversity and socio-economic setup of the communities. This forest harbors species that are endemic, economically and ecologically important, which requires urgent conservation measures that will enhance healthy regeneration and guarantee sustainable uses of these species. Although, *J. procera* and *P. falcatus* are both common in Boda Forest, the former has been more affected than the later for the extraction of timber. Thus, conservation priority should be given to Boda Forest due to its richness in endemism and natural resources diversity. In general, the following points should be taken into consideration concerning human impact on the forest.

1. Enhance diversification of livelihood (e.g poultry production and using improved varieties of crops),
2. Introduction of modern beehives,
3. Encourage ecotourism industry among local people.
4. Finally, further studies on soil properties, land use management system and detailed ethno-botanical studies are also required to explore the wealth of indigenous knowledge on the diversity of plants and their implications in conservation are recommended.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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