Tanzania Wildife Research Institute (TAWIRI)

PROCEEDINGS OF THE EIGHTH TAWIRI SCIENTIFIC CONFERENCE, 6th - 8th DECEMBER 2011, CORRIDOR SPRINGS HOTEL, ARUSHA, TANZANIA

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Acknowledgement

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SUKUMA LION KILLING IN THE KATAVI-RUKWA ECOSYSTEM

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ABSTRACT
In this paper we present data on the changing motivations for killing lions by Sukuma lion killers (wachezaji) around Katavi, and changing attitudes of households asked to make contributions to lion killers. We used structured interviews with 304 Sukuma households south of Katavi National Park about lion killing activities of young Sukuma men. In the second part of the article we discuss how a new implementation campaign is trying to change traditional Sukuma attitudes to lion killing and environmental issues in this remote area of western Tanzania.

INTRODUCTION
Lion conservation in Tanzania is pivotal to survival of African lions (Panthera leo) in the wild as four of the remaining six populations of over 1000 individuals are found in the country (Packer et al. 2011) . Direct killing of lions is arguably the greatest threat to lion populations in sub-Saharan Africa as identified by the Johannesburg 2006 lion conservation workshop (Frank et al. 2006). In East Africa, killing of lions is generally motivated by economic gains from foreign big game hunters although these financial rewards are rarely directly accessible to rural local communities. Instead, economic losses often drive lion killing by local communities. This constitutes the second major human threat to lion populations. Livestock depredation can inflict substantial economic costs on communities (Holmern et al. 2007), costs which often exceed the monetary face value of the animals lost because of additional social value of livestock. As such, most lion killing by local communities is a response to economic costs of losing livestock. Lion killing in response to livestock depredation is receiving considerable attention (Butler 2000; Holmern et al. 2007; Kissui 2008) and substantial conservation effort has focused on finding effective non-lethal methods of preventing (Ogada et al. 2003; Patterson 2004) or compensating for livestock loss (Maclennan et al. 2009). In situations where local communities and conservation initiatives agree on procedures for reducing lion livestock

depredation, initiatives can be highly successful (e.g., http://www.afrpw.org/projects/living_walls, and http://www.lionconservation.org/laikipia-predator-project.html) A third motive for killing lions is ritual killing which has been studied almost exclusively in the Maasai on the savannahs of Kenya and northern Tanzania (Hazzah et al. 2009; Ikanda & Packer 2008). Nonetheless we know that other agro-pastoralists groups such as the Wadatoga (Borgerhoff Mulder 1991) and Wasukuma also engage in both ritual and retaliatory lion killing. In this paper we explore lion killing by a major pastoralist group in Tanzania, the Wasukuma.Mpimbwe, an administrative division on the southern edge of Katavi National Park situated within the Katavi-Rukwa ecosystem (KRE), has been heavily colonized by the Sukuma. The KRE is the center of one of Tanzania's four key lion populations but recent surveys of a portion of KRE, Katavi Nationa Park, suggest the lion population here is much lower than is expected in this miombo woodland habitat (Caro 2008; Kiffner et al. 2009). In this paper we present the first results of investigating Sukuma lion killing in Mpimbwe and outline the steps being taken to try to reduce lion killing in the area. In Part 1, we outline the methods and results used to determine attitudes and motivation of the Sukuma to lion killing. In part 2 we introduce the Watu, Simba na Mazingira campaign (WASIMA) a multidisciplinary mitigation program focused on halting economically driven lion killing. The Sukuma, numerically the most populous tribe in Tanzania, have migrated to almost every region of the country and live adjacent to most of Tanzania's protected areas (Borgerhoff Mulder et al. 2009). Antagonism between the Sukuma herdsmen and lions is long standing. Their customs and habits may therefore be central to the fate of this species in both Tanzania and possibly Africa. Like many pastoralist/ agro-pastoralist groups, the Sukuma measure their wealth in head of cattle, little tolerance is afforded those who 'steal' their cattle. As with many cattle herding groups the dangers that lions pose to people and their livestock has resulted in the integration of lion killing into their traditions. The Sukuma richly reward someone who has killed a lion with cash and livestock. These payments are bestowed on the lion killer by his ukoo (kiswahili, clan). Previous (and ongoing) research shows that livestock depredation was the traditional precursor for Sukuma lion killing, and that with the promise of large rewards, a Sukuma lion killer can accumulate substantial wealth. Our project is based in KRE in Rukwa Region of western Tanzania. We are based in Mpimbwe (6.75, latitude: 30.75, longitude), an administrative division to the south of Katavi National Park (KNP). Created in 1974, KNP was set up principally to protect dry-season assemblages of large mammals (Caro 2008). Mpimbwe is comprised of 22 villages (this number increased from 14 in 2009) and serviced by a dirt road. Many of the villages lie off this main road and are largely inaccessible by vehicle. Mpimbwe was first settled by Sukuma in the early 1970s. Today their population is thought to outnumber the indigenous Wapimbwe people to whom they are economically dominant. Increasingly the Sukuma are being given many important positions within local government. Figure 1 shows the Katavi-Rukwa Ecosystem and Mpimbwe with the main villages.

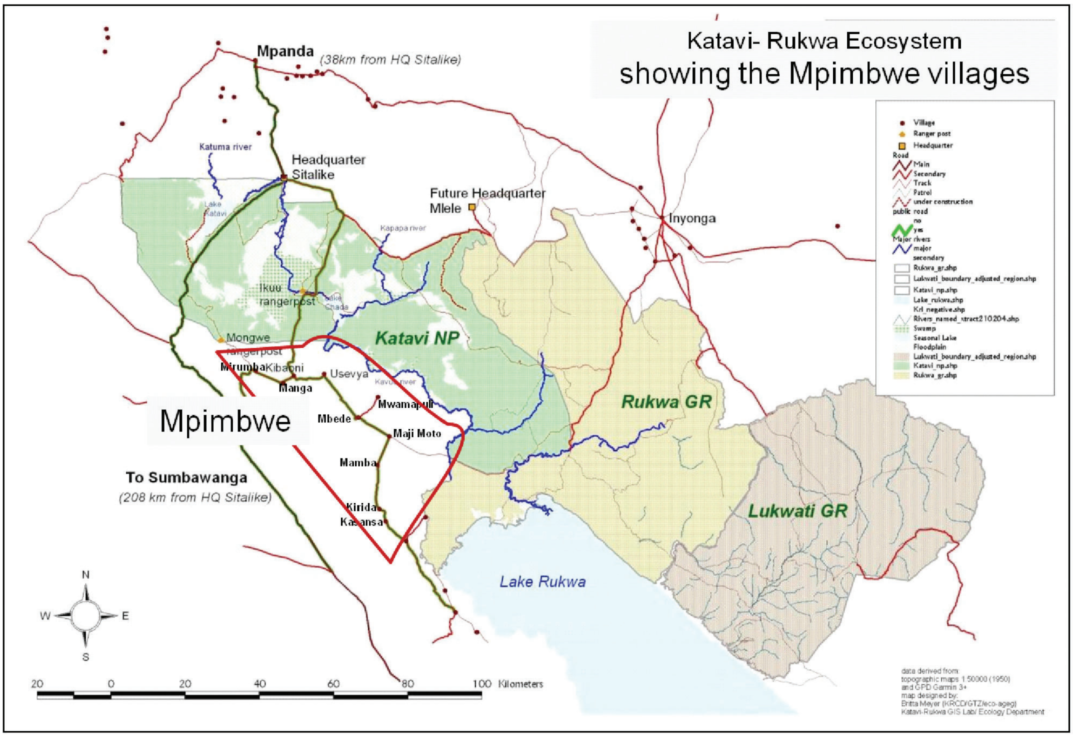


Figure 1: A map showing the Katavi – Rukwa Ecosystem, Mpimbwe and the location of the main Mpimbwe villages.

METHODS

EF sampled 304 households in Mpimbwe, approximately 40% of Sukuma households across 12 or the 22 Mpimbwe villages. Households (made up of large extended families, 5-45 individuals) were selected randomly from sub-village lists, and stratified to represent Sukuma concentrations. All interviews were conducted in a mix of Kiswahili and Kisukuma, depending on interviewees' preferences, and with the assistance of local Sukuma assistants for translations (from Kisukuma into Kiswahili), introductions, and general cultural guidance and acceptability. Some households refused to answer questions about lion killing, in which case the interview was abandoned. The interview was modified slightly following the preliminary research phase explaining the variation in number of respondents. All interviews were conducted with a primary interviewee (the household head where possible) other viewpoints of household members were recorded too. In all households baseline socioeconomic variables were collected. To quantify the livestock depredation by lions households we asked to report the number of cattle, goats and sheep lost to lions in the last year as well as the when the last time lions visited the homestead. In order to determine the prevalence of lion killing, a proxy of 'number of lion-dancer visits to the household' was used. Households were asked to recall the number of visits by lion-dancers. As each lion killer only kills one lion, we can infer that a change in the frequency of lion killer visits to households has resulted from an increase in the number of lions being killed. Householders' perceptions of the historic and current motivation of the Sukuma to kill lions, their attitudes to changes in these motivations and their associated responses as indicated by the size and nature of gifts bestowed were gathered. The number of households refusing to reward a lion dancer was correlated to the total number of lion killer visits using Person's correlation co-efficient (SPSS, v. 18). Obtaining reliable information about the killing of endangered species is difficult. Rather than ask direct questions about this sensitive issue, questionnaires focused on a change between the traditional and current practice of lion killing in recognition that culture is not static but ever evolving cross generationally.

RESULTS

Livestock depredation is not rife in Mpimbwe. Only three households reported having ever lost livestock to a lions (n=304) and an average of 2 households reporting being visited by a lion (without necessary leading to livestock depredation) in any year from 1990. Despite the minimal threat lions appear to pose to the livestock of the Sukuma in Mpimbwe, the number of lion-dancers seems to be increasing. Figure 2 shows the number of households reporting being visited by a lion dancer since 1990. Figure 4 shows the distribution of lion killer visits to Sukuma households and the number of visits the household has received by different lion killers since 2004. There is a notable increased in the number of households visited by lion killers in the northern villages compared to the southern villages. Correlated to the number of households visited by a lion dancer in each year is the number of households that refuse to gift a reward to the lion killer ($r= 0.939$, $n = 21$, $p > 0.001$ Figure 5). Throughout the 1990's no household that recorded being visited by a lion killer refused to reward them where as from 1998 the proportion of households visited by a lion killer who refused to gift a reward has steadily increased (Figure 3). Additionally traditional and contemporary rewards have changed. Cattle was the traditional reward gift (stated as a traditional gift by 94% of households, with only goats and money being cited as traditional gifts by 57% and 40% of households respectively). Goats and cash dominate contemporary reward payments - the number of households stating that cattle are given dropped slightly to 82% with a marked rise in the number of households saying that the lower value gifts of goats or some cash rose to 84% and 73% respectively. Finally, Figure 3 suggests that this changing pattern of lion killing is recognized by households who report a very different distribution of circumstances for killing lions in traditional versus contemporary times. Ninety four percent (n = 236 households) described the traditional occasion for killing of lions as being in the boma or while grazing their cattle as a response to livestock loss compared with only 39% of households that reported this for Sukuma lion killing in Mpimbwe today. In contrast only 6% of interviewees said that the Sukuma historically hunted lions where as 66% of households said that the Sukuma hunt lions in Mpimbwe. A change in the motivation

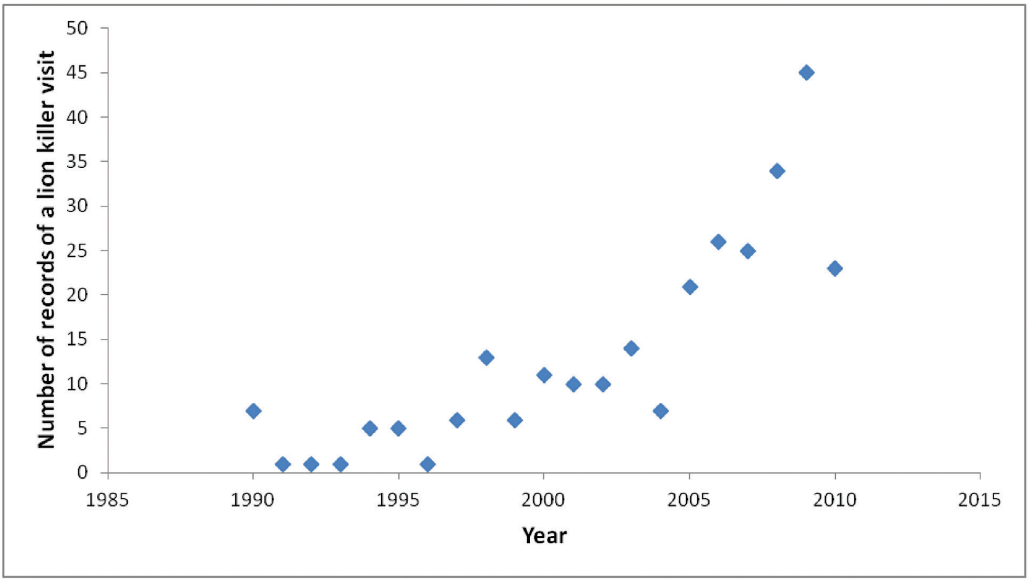


Figure 2: Household visits by lion killers. 1990-2010

for lion killing was reported in fifty three percent of cases as being economic gain (to get rich), this change having taken place from the late 1990's – early 21st century.

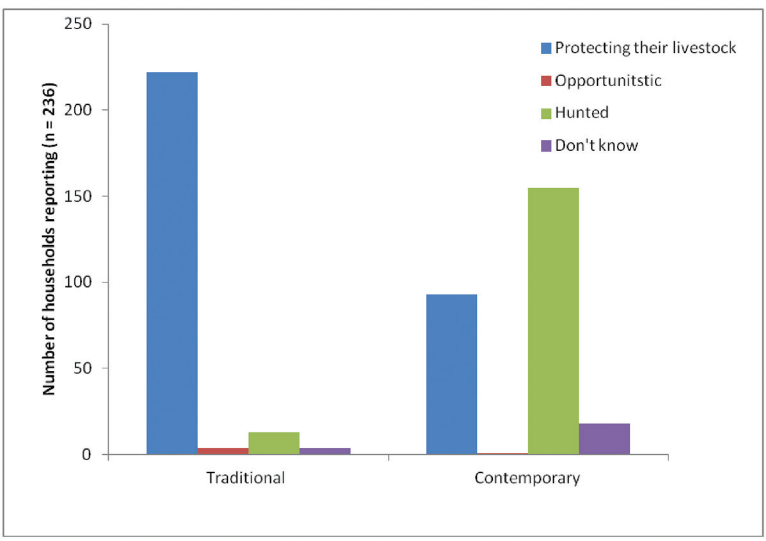


Figure 3: The variation in responses from households asked to state the traditional and current reasons for lion killing by a Sukuma.

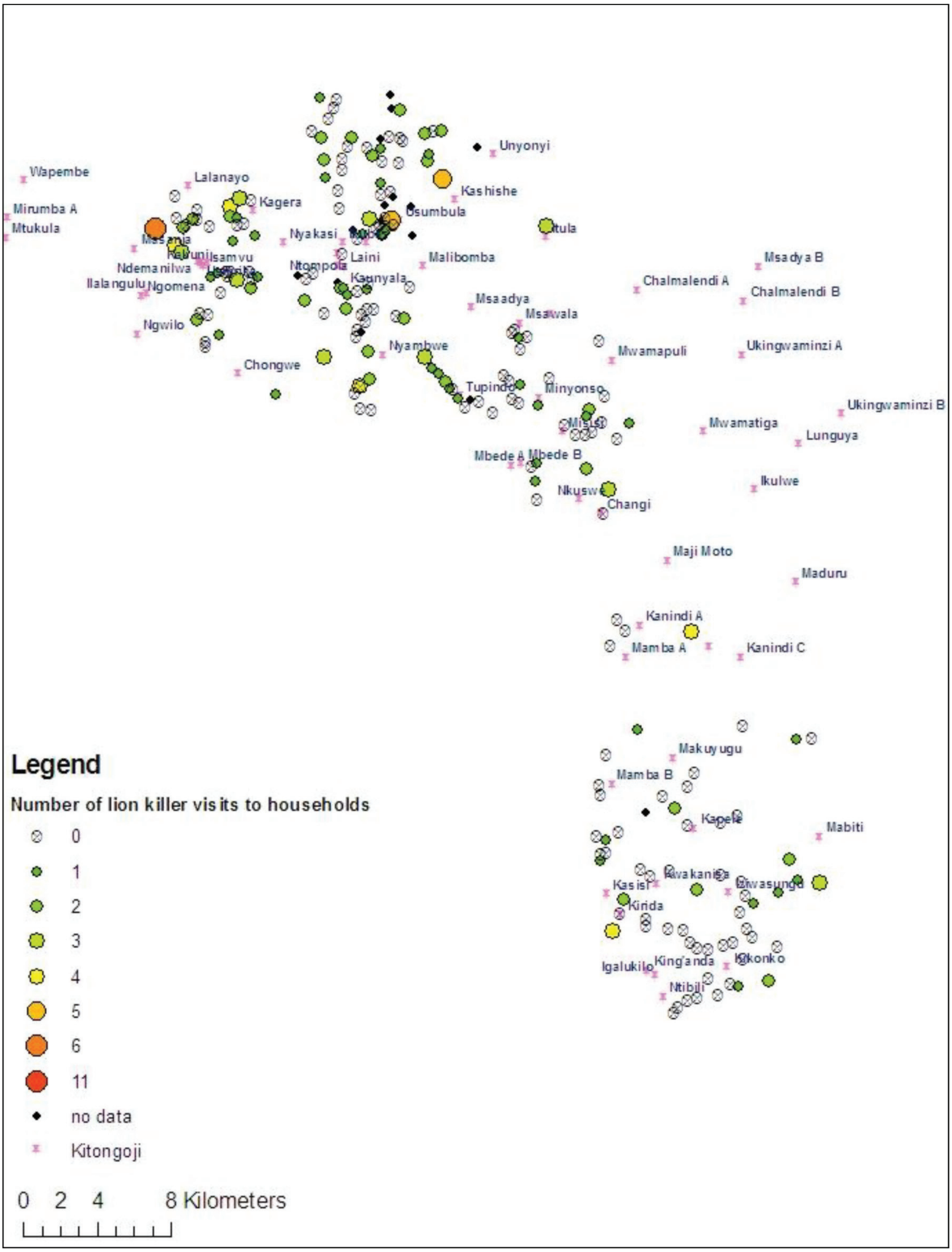
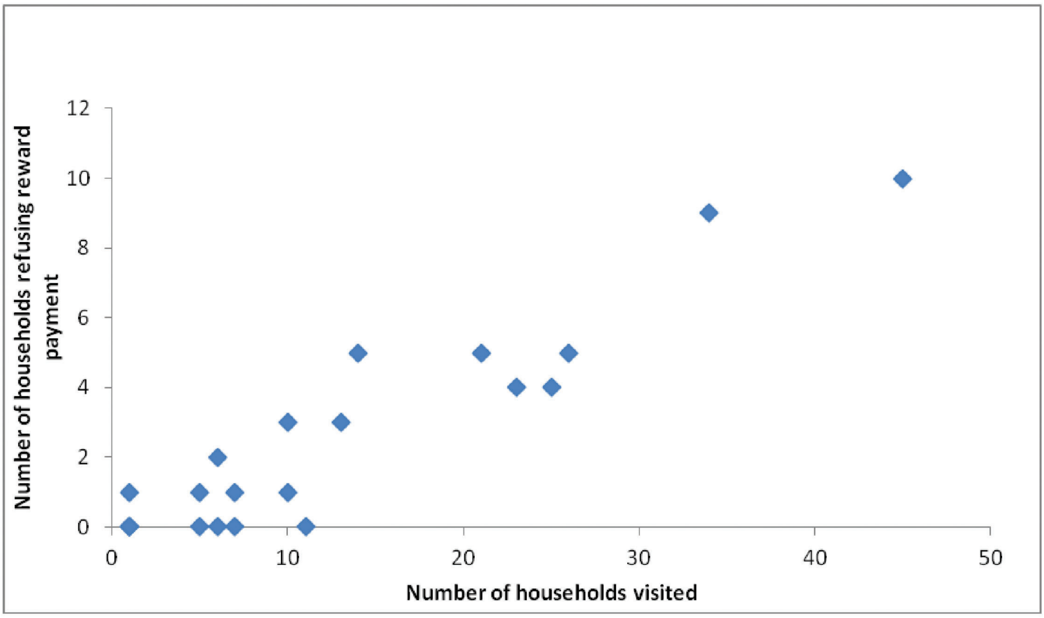


Figure 4: Location of each surveyed household across Mpimbwe and the number of lion killer visits to each sampled household. The map also shows the location of each sub-village centre across Mpimbwe.



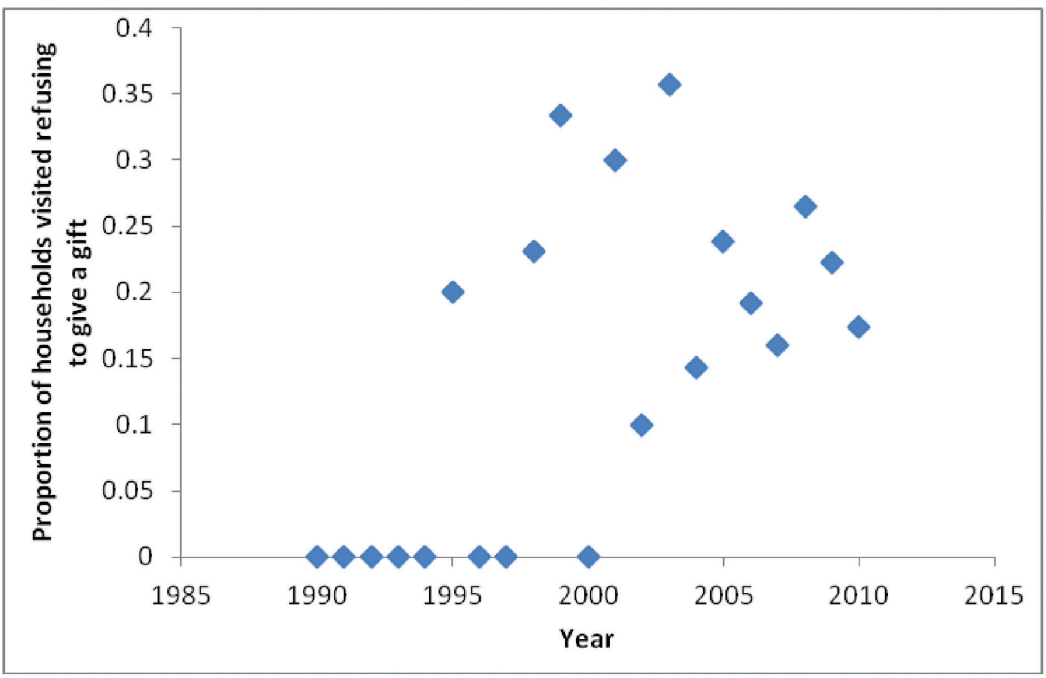


Figure 5: Proportion of households visited by a lion killer who refused to reward.

DISCUSSION

Our preliminary analysis shows that the number of lion killers frequenting households in Mpimbwe has risen steeply in recent years, that lion killers are receiving lower value rewards than they did traditionally and that as the number of lion killers increases so does the number of refusals to reward. The sukuma appear cognizant of the changing traditions regarding lion killing with the contemporary occasion for lion killing being during a hunt as opposed to the traditionally cited occasion of being either whilst grazing their cattle or in the boma. Furthermore there is very little evidence of livestock depredation by lions, further supporting the view that the traditional reasons for lion killing do not exist in Mpimbwe. So why has lion killing increased when there is negligible livestock depredation by lions? It seems that population growth, extensive rice cultivation and livestock grazing have resulted in widespread habitat degradation and land shortages. As a consequence of its remoteness, non-mechanized agricultural production is the key to economic prosperity in Mimpbwe. However, many Sukuma young men are disillusioned and disenchanted with a life of farming. Today, rather than using agricultural profits to buy livestock and accumulate wealth, they are organizing lion hunts into the national park, motivated not by lion predation of livestock but simply the promise of traditional reward payments for lion kills. In other words, it would appear that the quest for economic gain (reward payments for killing a lion) rather than the prevention of economic loss (livestock depredation) is driving lion population decline as traditional 'lion-killers'. Interestingly, although it appears that young Sukuma men hunt lions because their relatives will reward them, the profitability of killing a lion seems to be falling. Our results show a shift in the main reward from cattle to lesser gifts of goats and money. Reward payments are controlled by household heads who determine the size of the gifts bestowed upon the lion-killer. This shift indicates a growing intolerance by the Sukuma of those that hunt lions for profit, or indicates a decrease in general family income. Irrespective of why households are refusing, decreasing profitability of lion killing can be used to leverage our mitigation project.

Mitigations

In response to the findings of the research, the Watu, Simba na Mazingira (WASIMA) campaign was established to reduce lion killing and environmental destruction in Mpimbwe. WASIMA was launched on the 23 August 2011 in a workshop attended by stakeholders of various backgrounds including representatives from District officials, Wardens and Game Officers from Katavi NP and Rukwa/Lwafi GR respectively. Village Chairpersons, Village Executive Officers and influential community elders were present. We are working initially in eight of the 22 villages in Mpimbwe identified as experiencing the greatest environmental damage or propensity towards lion killing.

The goals of WASIMA are:

1. To reduce lion killing in areas adjacent to Katavi National Park (KNP), Rukwa and Lwafi Game Reserves.
2. To identify, train and empower community members and institutions that are willing to bear the costs of policing and/or reporting specified environmental abuses.
3. To facilitate environmental education in schools and sensitization of local communities at large to environmental issues (with a specific focus on the Sukuma).

Campaign Activities

Environmental education

Conservation awareness amongst the Sukuma does not run high.. Although few cattle are killed by lions (and lions are rarely seen), lions are still perceived as abundant and classed as a dangerous threat to the Sukuma. Without awareness of the importance of lions within the ecosystem and their precarious conservation status we cannot hope to enlist support for more targeted mitigation strategies. To this end WASIMA will implement a community wide education program to build awareness about the rarity and population status of lions, to foster positive attitudes towards lions and wildlife, and to facilitate knowledge transfer in both directions between National Parks staff and local communities. Field trips will provide opportunities for primary and secondary school students and WASIMA targeted institutions (see above) to experience the touristic and recreational value of protected areas with healthy ecosystems and wildlife. This will be executed in collaboration with KNP, using their vehicle designated for this purpose. Educational programmes (from wardens/rangers in the Park) will be included. In order to increase local institutional knowledge of environmental processes, environmental regulations, WASIMA will be organizing training sessions and workshops for village government representatives, lead members of the Sungusungu and Sukuma households heads in conjunction with KNP and Wildlife Division (WD) community conservation officers, and World Wildlife Fund's (WWF) WMA coordinator.

Policing/Reporting

Lion programmes in Amboseli (Kenya) and Ruaha are experimenting with the idea of engaging traditional institutions in environmental protection. WASIMA will work with the Sungusungu, an independent informal traditional Sukuma institution with enormous moral authority in the area, which is responsible for maintaining law and order through the tight regulation of Sukuma society (Paciotti et al 2005). The adoption of an anti-lion hunting policy by the Sungusungu Could be an enormous first step for lion conservation in the area. Despite their controversial activites in other parts of the country, they are a respected group in the Mpimbwe area. Therefore, we believe that given the position the Sungusungu hold in Mpimbwe harnessing their power in conjunction with strong training from TANAPA, WD and other authorities, may be the most effective method of halting the spread of economically-motivated Sukuma lion hunting adjacent to KNP

Clearly there is a movement within Sukuma households to reduce reward payments. During the first WASIMA workshop, there was strong agreement among local leaders, village government officials, representatives from TANAPA and WD, and the DED himself that this strategy might help mitigate the current environmental problems facing Mpimbwe - in areas outside of the jurisdiction of the WD and TANAPA. To this aim WASIMA will work with them to encourage the adoption of an anti-lion hunting policy and support a unilateral refusal to reward those who hunt lions in order to remove the economic incentive, and thereby reduce the attraction of lion killing as a 'get rich quick' strategy for young Sukuma men.

Learning what works

To ensure that we learn from our project success and failures, we will be quantifying not only changes in lion killing and implementation of project objectives but will evaluate the causes of success. By examining both the learning processes and outcomes involved in a range of educational approaches, through workshops, interviews and questionnaires completed by Peter Genda and those taking part in project activities, we hope to able to identify how various approaches impact the knowledge, attitudes and behavior of local people with regards to lion conservation. We hope to determine qualitatively how each strategy contributes to the environmental literacy of the community, and potentially to the desired outcome of reduced lion hunting in KNP. In this way WASIMA aims to be a highly reflective program and one that can truly identify its own strengths and weakness from which it can build. In addition, by involving local leaders as well as agency and NGO representatives in the decision-making, development and testing of strategies to reduce lion killing, WASIMA is applying participatory approaches to both conservation and research on education and out reach efforts.

CONCLUSION

This project has uncovered an extensive and rapidly changing cultural practice that is impacting Western Tanzania's lion populations. In response to these research findings and the concerns of many members of he community, we have begun a mitigation campaign (WASIMA) to reverse and halt manipulation of traditional motivations for lion killing and address other environmental problems in the area (deforestation, etc.). This is an exciting and challenging program and is just in its early stages.

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STATUS AND MITIGATION MEASURES OF ELEPHANT CROP RAIDING IN AREAS ADJACENT TO GRUMETI – IKORONGO GAME RESERVES, NORTHERN, TANZANIA

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ABSTRACT

Twelve villages located adjacent the Grumeti-Ikorongo Game Reserves (GIGRs) and part of the Serengeti National Park (SENAPA) in Bunda and Serengeti districts were selected to assess elephant crop raiding incidences and mitigation measures from 2006 to 2009. The study aimed at identifying the type of conflicts, determine the magnitude, spatial and temporal patterns of elephant crop raiding incidences, and the type of the mitigation methods applied. Arc GIS, version 9.3 was used to analyze spatial data while the SPSS was used to analyze the magnitude and temporal patterns. Temporal trends indicated two activity peaks of elephant crop damage incidences, the highest peak started from April to June and the lower from September to October, these periods corresponded with the crop harvest time and maturity of perennial root crops respectively. The spatial distribution of crop raiding incidences showed a series of clumped conflict zones confined in a narrow band of villages within an average distance of 1.35 km away from village centres to the GIGRs and SENAPA boundaries. The magnitudes of HEC were not similar across the villages as they were influenced by distance between the centre of the villages and the protected areas boundaries ($r = -0.848$, $p < 0.001$). About 45% of the farmers used ineffective traditional methods to deter elephants, while 48% of them did not deploy any method and 7% used an integrated chilli based method that showed effective deterrent results therefore, the study recommended for up-scaling in order to reduce HEC to more tolerable levels.

INTRODUCTION

Human-elephant conflicts, particularly crop raiding is a perennial conservation problem that appears to be increasing wherever elephant range overlaps with human settlement and cultivated areas (Newmark et al.,1994; Hoare, 2000; Walpole et al., 2004). Changes in the sizes of human and elephant populations, and lack of land use plans, have increased the competition between humans and elephants for spaces and resources (Newmark et al.,1994; Hoare and du Toit, 1999). The rapid human population growth estimated at the rate of 2.9% per year for Serengeti and Bunda districts for the year 2002 respectively (Tomas et al., 2004) coupled with increased human activities in the adjacent land to the protected areas (Kaltenborn et al., 2003), and the increase in number of elephants in the Grumeti-Ikorongo Game Reserves (GIGRs) has resultedinto increased HEC in the area (Walpole et al., 2004). Additionally, the change of conservation practise of GIGRs from hunting to conservation concession by the Grumeti Reserve Company acceleratedimmigration of wildlife species probably from SENAPA particularly the elephants from 21 individuals reported in 2002 to 355 elephants counted in the GIGRs in September 2003 (Goodman, 2003; TAWIRI, 2002). Like in many other parts of Africa, communities do report conflicts attributed to elephants over crop, property damages and the threats posed to human life as significant costs of living adjacent to protected areas, where crop damage is often the major cause of conflicts (Newmark et al., 1994). In Bunda and Serengeti districts, elephant crop raiding is a relatively recent phenomenon which appeared to reach epidemic proportions in 2004 (Walpole et al., 2004). Since 2004 data on crop raiding by elephants have been collected at both village and district levels. For example, in Serengeti district, local communities apparently reported, a total of 323 ha (732t) of damaged crops by elephants in the 2003/04 season (Bitala, 2004). Most reports of elephant crop losses are based on surveys of local peoples' perception of the problem and its impacts. It is recognized that the perceived and actual costs of such conflicts do not always match (Masunzu et al., 1998). This presents a failure to point out the actual magnitude of the problem and the appropriate intervention to wildlife management authorities faced by the demand of local communities for problem animal control (Baldus, 1991).

Bitala (2004) reported that, people's estimates of the areas of crop farms damaged by elephants were inaccurate in the Serengeti district. To many local farmers, an area of 0.404 ha. is an area of land that takes two days to plough by oxen, thus measured more broadly in time rather than space. This becomes more difficult to accurately estimate the size of cultivated damaged farms, which may not always reflect the loss of yield (Walpole et al., 2004). The limitations in the methods and uniformity of HEC data collected across the districts are therefore evident. Data which rely on farmers' report of crop raids quite often overestimate the losses. Equally, the nature of the records taken by each village differs and contains no spatial or temporal information. This highlight the need for an accurate assessment of crop damages to determine the extent, spatial and temporal patterns of HEC in the study area.

Objectives

General objective

The overall objective was to assess elephant crop raiding incidences in areas adjacent to Grumeti-Ikorongo Game Reserves, northern Tanzania.

Specific objectives

- To identify and determine the patterns of elephant crop damage incidences
- To determine the extent of crop damages caused by elephants

MATERIALS AND METHODS

Study area

The study area is located in Serengeti and Bunda districts which lie between latitude 1˚28' and 3˚17'S and longitude 33˚50' and 35˚20'E (Kaltenborn et al., 2003) (Fig. 1).

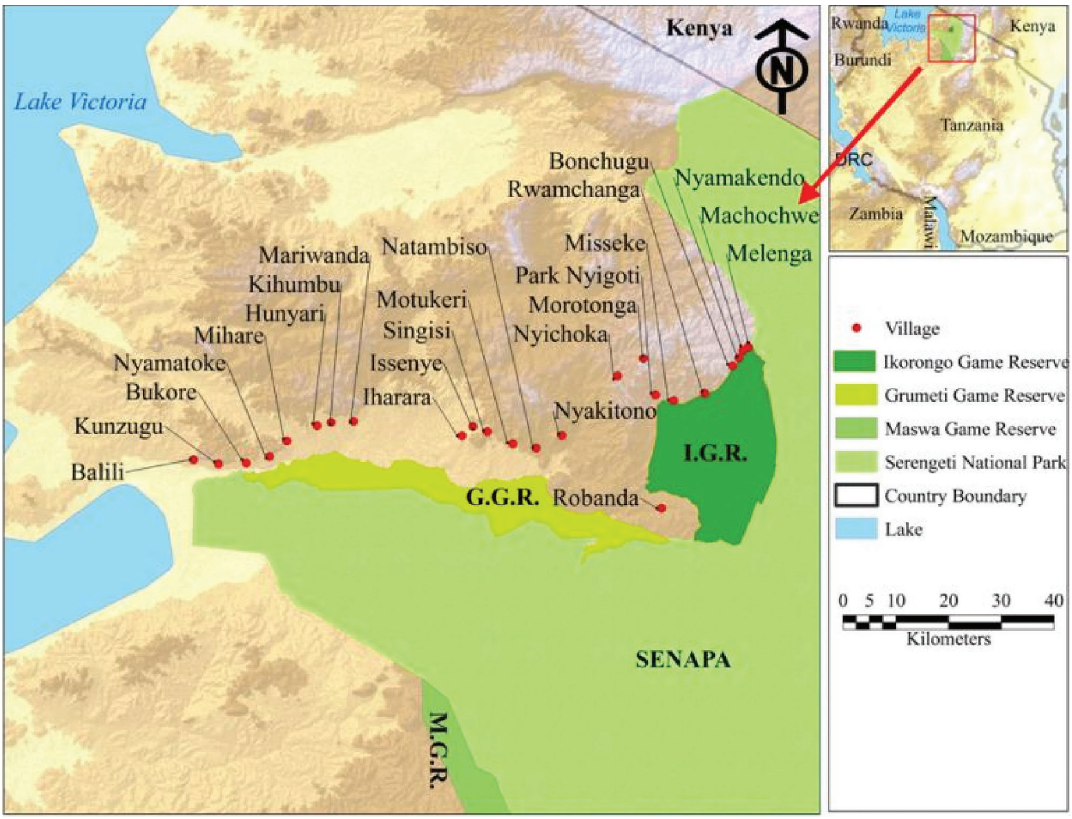

Figure 1: A map of the north-western part of Serengeti ecosystem showing the study villages adjacent to Grumeti-Ikorongo Game Reserves and Serengeti National Park

Research design and sampling procedure

Both longitudinal and retrospective-prospective study designs were used to collect data during the entire study period. For prospective data collections, field visits were conducted twice during the first and fourth week of a month. A purposive sampling technique was used to select 12 out of 24 villages whose centres were less than 5 km from the protected area boundary (Bluman, 1997; Kothari, 2004).

Data collection

A standardized HEC data collection and analysis protocol developed by Hoare (1999a,b) and adopted by AfESG for use in HEC situations in some African elephant range states (Hoare,1999c; Parker and Osborn, 2001; Malima et al., 2004) was used. The present study adopted the same method to enable comparison with other elephant range states, and recommend management intervention strategies to minimize HEC. During the study, four local enumerators were recruited and trained to assess and record primary data particularly elephant crop raiding and other conflict incidence locations by use of a simple Geographical Positioning System (GPS) device and to assess crop damages. When elephant crop raiding incidents occurred, enumerators were informed through the existing village community communication networks and visited the incident site as soon as possible. On the site, the enumerator identified and recorded the type of conflicts, the name and locations of village in Universal Transverse Mercator (UTM) coordinates and other details on a standard elephant damage record form

Assessment of elephant crop damages

Once crop damage occurred, the enumerator identified the type of crop raided, determined the area of the cultivated farm and damaged portion (s) by pacing. The age and quality of crop from damaged farm(s) were assessed and recorded using a method described by Hoare (1999a). Crop ages were determined and classified into three categories namely seedling (crop growth stage from emergence to pre-flowering stage), premature (crop growth stage from flowering to fruiting), or mature (plant growth stage after fruiting to the point of harvest), while the quality of undamaged crops were assigned three classes as poor (state of plant body under bad crop husbandry, poor soil fertility, disease and pest attack or unfavourable climatic conditions), medium (plants under average crop husbandry, soil fertility or climatic conditions) and good (plants growth conditions under optimal crop husbandry, soil fertility, favourable climatic conditions and absence of disease or pest attack). Age categories for crops were assigned numbers 1, 2, and 3 for seedling, premature and mature growth stages respectively. Quality categories were also assigned numbers 1, 2, and 3 for poor, medium and good respectively.

Assessment of other incidences

Other types of incidences like, human death or injury, destruction of food stores or water structures, human activities interference, killing or injury of livestock and retaliatory killing of elephants were recorded as they occur. Existence of any mitigation techniques used to deter elephants from crops and property damages were also recorded and the number of raiding attempts and damages inflicted by elephants were noted and recorded where possible.

Data analysis

The GPS point data projected into UTM coordinates were imported to Arc GIS 9, Version 9.3 for spatial analysis. The digitized shape files of the GGR, IGR, and SENAPA were assembled from maps provided by TAWIRI in order to provide a spatial map of HEC. Crop damages incidences were assigned six categories based on the percentages of damaged portion of the cultivated farm, categorized on the ranges of (< 5%; 6-10%; 11-20%; 21-50%; 51-80 %; and > 80%). Furthermore crop damage level were assigned three levels, low (< 5), medium (6-8) and high (> 9) by combining points for the age, quality and damage (Hoare, 1999b). The higher the score of combined points (age + quality + damage) for an incident, the more serious the damage observed (Hoare, 1999a). The number of elephant incidences, distances and size of damaged farms, type of conflicts and the mitigation methods used were imported into Microsoft excel and Statistical Package for Social Science (SPSS) program for calculating percentages, standard deviations, and regression analysis. Area of farms cultivated and damaged portions were obtained from the calibrated enumerators paces in order to standardize the measurements. Additional data for the past three years (2006-2008) were retrospectively retrieved from the district game officers in Bunda and Serengeti districts and from research repository at Serengeti Wildlife Research Centre (SWRC), TAWIRI library and internet.

RESULTS AND DISCUSSION

Types of crops damaged by elephants

From 2006 to 2009 a total of 1618 elephant crop raiding incidences were recorded, with an average of 2 - 3 small plots damaged per incident. About 10 categories of both cereal and cash crops were raided (Fig.2). In some incursions sisal plants and indigenous trees were damaged during the dry season.

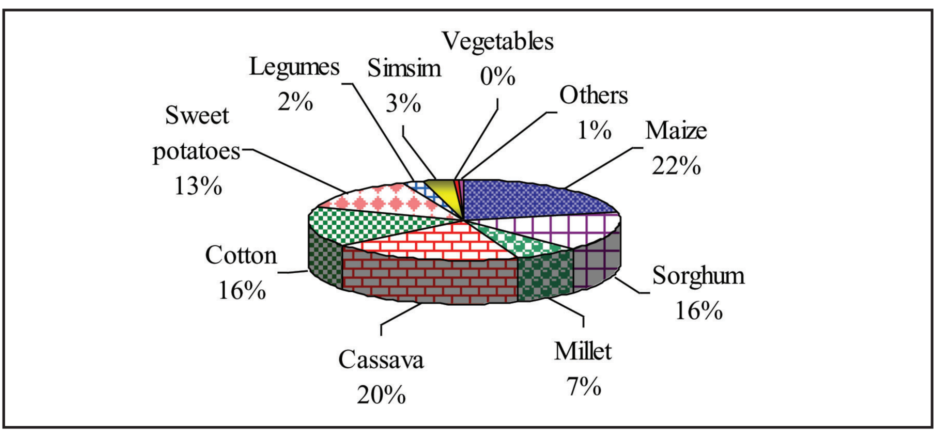

Figure 2: Proportions of crops damaged by elephants in villages adjacent to GIGRs and SENAPA (N = 1618)

Patterns of crop raiding incidences

Temporal pattern

Temporal trends indicated two peaks of elephant crop damage incidences. The highest peak from May to July and a lower peak appeared during the dry season between September and October (Fig.3). These time periods corresponded with the crop harvest time and availability of mature perennial root crops respectively.

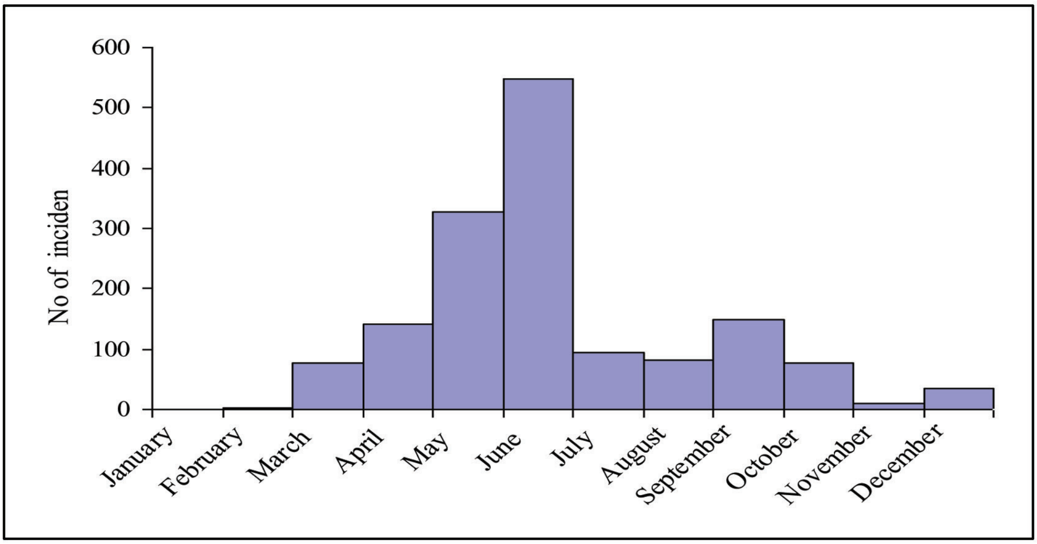

Fig. 3. Elephant crop damage incidences in areas adjacent to GIGRs and SENAPA as recorded from 2006 to 2009

Elephant crop raiding incidences did not occur on daily basis, elephants usually visited in groups ranging from 1 - 10 individuals and raided an area persistently every day for 1 to 3 nights raiding an average of 2-3 small crop fields within an incursion, and then disappeared for many days or weeks before returning again (Box 1).

Box 1: Elephant crop raid incidences in Rwamchanga village in Serengeti District.

Between April and May, 2007 five incidences of elephant crop damage were recorded in Rwamchanga village. On 15, 18 and 20 of April, elephant damaged a total of 66 small crop fields. They returned again on 10 and 26 May, and raided a total of 37 small crop fields of mainly maize and sorghum.

Crop raiding was observed to be high during night time, starting from 1900 h to 2100 h depending on the distance of the farms from the elephant domicile zone. Most raiding incidents were reported to occur from 2200 h to 0200 h. Elephants were occasionally sighted resting in thick vegetations at the border to the protected areas and along the Robana river mostly between 1600 h to 1800 h. Sometimes when elephants successfully raided crop fields, they appeared to spend some hours in the same field although occasionally moved to a nearby crop field to continue feeding on preferred target crop.

Spatial pattern

From 2006 to 2009 the spatial distribution of crop raiding incidences showed a series of clumped conflict zones confined in a narrow band of villages adjacent to the GIGRs and SENAPA boundaries (Fig 4). The narrow band of clustered conflict incidences were related to the nature of subsistence farming system practiced by the local inhabitants in the area as reported by Kideghesho (2008) and the availability of fertile soil on the adjacent land to the GIGR's.

For the period of four years consecutively, Manchira ward experienced the highest number of crop raiding incidences (Fig. 5). This observation is probably attributed to the fact that most crop fields were found nearly adjacent to IGR boundary. On the other hand, villages at Hunyari ward namely Mariwanda, Kihumbu and Hunyari villages experienced the lower damage score points, with the highest mean rank (Appendix I). In The area farms are located at a relative longer distance of an average of 3.9 km from the protected areas. Villages in Chamriho, Mcharo and Kunzugu wards had an average damage scores points and mean rank, with an exception of Nyamatoke village. In these villages, crop fields were located slightly closer (range of 0.5 to 1.0 km) from the protected area boundary. Interestingly, villages in the Ikoma ward in particular the Robanda village experienced the minimum number of crop raiding incidences regardless of its location of being encircled by the two game reserves and SENAPA.

Park Nyigoti village appeared to have high damage scores and the lowest mean rank probably due to the presence of Nyankimwa dam that directly attracted elephant as a source of water. Elephants raided mainly root crops (cassava) on their way to the dam particularly during the dry season as opposed to wet season where elephant primarily raided crops. The higher the number of elephant damage incidences the greater the damage scores and the lower the mean rank thus the higher the conflict level. The mean of the three ranks (total incidents, serious incidents and damage scores) is very useful for decision making by the management authorities.

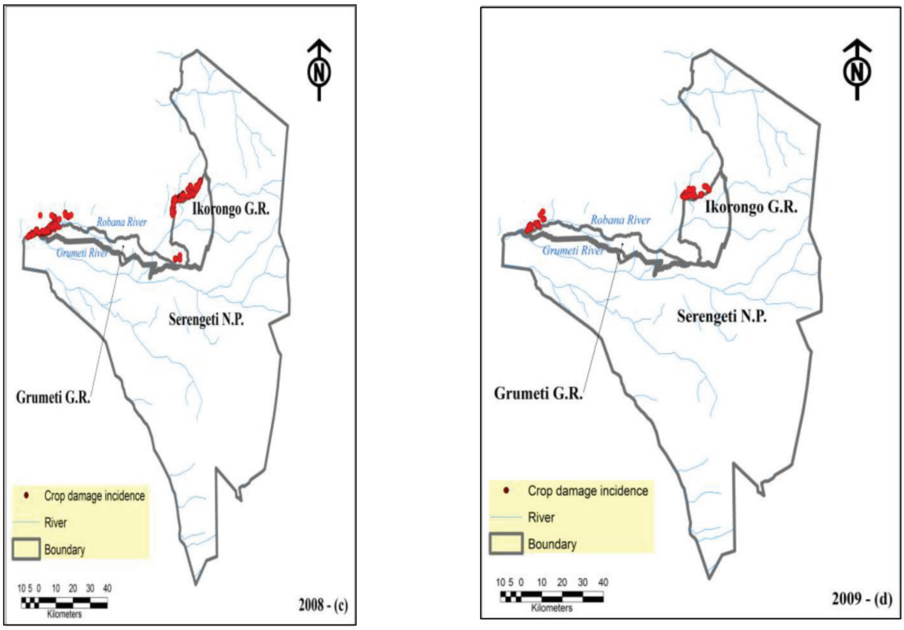

Figure 4: Spatial distributions of elephant crop damage incidences in villages adjacent to GIGRs and SENAPA as recorded from 2006 to 2009

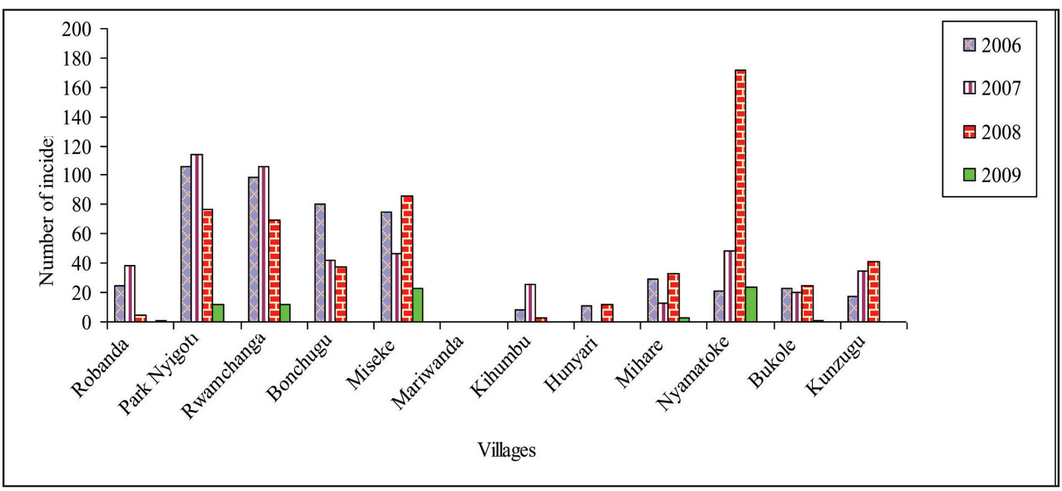

Figure 5: Elephant crop raiding incidences in some villages adjacent to GIGRs and SENAPA as recorded from 2006 to 2009

The Magnitude of elephant crop damages

The magnitudes of elephant crop damages in villages adjacent to GIGRs and SENAPA were not similar. They appeared to be largely influenced by the distances of the crop fields to the protected areas boundaries. Crop damage incidences were inversely related to the distances from the crop fields to protected area boundaries ($r = -0.84$, $p < 0.001$). Comparison of the sizes of the damaged farms over years indicated significant differences in magnitude of damaged farms (F-test = 16.29, $p = 0.001$, $df = 3$), where the yearly sample mean of the damaged farm sizes for 2006, 2007, 2008 and 2009 were 4312.80 ha, 5555.60 ha, 8949.60 ha and 2660.00 ha, respectively.

Methods used to mitigate elephant crop damages

About 45% of the farmers used ineffective traditional methods to deter elephants while 48% of them did not deploy any method and 7% used chilli method that showed effective deterrent results.

Traditional methods

The ineffective traditional methods used were noise making and use of fire combined with night guard. For example, during the 2008/09 crop season, elephant showed 96% success for a total of 628 raiding attempts. In some villages farmers were compelled to harvest their crops prematurely to avoid damage by elephants (Plate 1).

Chilli deterrent method

In the study area, the use of chili deterrent method was introduced in 2007. A chilli based method involves the use of the mixture of used engine oil and grounded chilli, pieces of clothes made up of cotton materials, sisal ropes and wooden poles of about 4 m long. (Plate 2). Chili bricks made up of a mixture of cow dung and grounded chili were used.

Plate 1: A heap of prematurely harvested maize cobs at Rwamchanga village bordering the IGR in Serengeti district in 2008

Plate 2: Un-raided maize farm at Rwamchanga village in Serengeti District protected by a chilli deterrent method

In this study few farmers (7%) adopted the chili deterrent method that showed good protection against marauding elephants. Where properly used, elephants avoided chili fenced farm by changing direction and invaded adjacent unfenced farms. The method created a positive altitude to most farmers in the study area.

CONCLUSION AND RECOMMENDATIONS

The chili method is recommended for up scaling as it requires cheap, locally available materials and low technology for its application. The study also recommends;

- Continuous monitoring of crop raiding incidences.
- Monitoring of local altitude and activities over time to discover the extent to which interventions have improved local support and tolerance.
- Encourage clustered cultivation zones away from protected area boundaries
- Encourage ring cultivation with crops most preferred by elephants planted at the centre.
- Strengthen community education awareness through TANAPA outreach program to publicise the effectiveness of chilli deterrent method.
- Advise the government to include the set of best practices of HEC mitigations strategies in the guidelines to support the implementation of the Wildlife regulation of dangerous animal damage consolation, 2011.

ACKNOWLEDGEMENTS

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VIEWING HUMAN-ELEPHANT CONFLICTS FROM A NEW ANGLE: THE STUDY OF THE CONFLICTS ALONG THE EASTERN BOUNDARY OF UDZUNGWA MOUNTAINS NATIONAL PARK, TANZANIA

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ABSTRACT
Elephants are regarded as the most dangerous species on human-wildlife conflicts lists. They damage crops, forcing people to retaliate by either killing or injuring them. This radically threatens long-term plans for elephant conservation. This paper focuses on understanding human-elephant conflicts by discussing 1) the spatial and temporal distribution of elephant crop-raiding incidences, and, 2) local communities' perception of the human-elephant conflicts. The study has found that relative distance between villages and protected area boundaries is not always an important factor in understanding human-elephant conflicts. The identification of commonly used elephant trails may be crucial when analyzing spatial variation in crop-raiding incidence between villages in mountain settings (a "Funnel Effect"). Seasonality is not always a significant factor in predicting crop-raiding patterns. Types of farming such as irrigation may factor into crop-raiding dynamics. Local communities demand fences around protected areas and that they should be compensated when elephants raid their farms.

INTRODUCTION
Elephants, though regarded as special species economically and ecologically, are also regarded as the most dangerous species on human-wildlife conflicts lists (Berger, 2001; Dublin & Hoare, 2004). In Kibale, Uganda elephant damage was found to be highly localized but catastrophic where it did occur, destroying half of the average household annual income (Bond, 1994). Average loss of crops raided by elephants ranged from 0.2% (Niger) to 61% (Gabon) of planted fields, and costs per affected farmer ranged from $60 (Uganda) to $500 (Cameroon) per farming season (Adams & McShane, 1996). Elephants' damage in the Greater Ruaha ecosystem, Tanzania resulted in an average loss of 40% of all crops that were planted. This damage often forces people to retaliate by either killing or injuring the problem elephants (Hoare, 2001; Dublin & Hoare, 2004), ignoring anti-poaching campaigns or even displacing elephants. This radically threatens long-term plans and strategies for conservation of elephants and other wildlife at large (Dublin & Hoare, 2004; Lamarque et al., 2008).
Elephants' crop raiding behavior is influenced by their habitats conditions, adjacent

agricultural landscape (proximity to park boundary - Barnes, 2002; Danquah, 2003; Chiyo et al., 2005) with its associated different types (Danquah, 2003; Chiyo et al., 2005) and number of crops (Barnes et al., 2003) and natural factors such as moon phase and rainfall (Barnes, 2002). However, crop raiding activity appears to be stressful to the elephants themselves (Ahlering et al., 2010), as it entails risk-taking in relatively unfamiliar and open habitat.

Reports of elephant crop damages in areas along the eastern side of Udzungwa Mountains National Park (UMNP) began to increase approximately two years ago when elephants' raiding intensified (personal observations, 2010). The loss of wildlife corridors and lack of buffer zone means that elephants and other animals now venture regularly outside the park boundaries and are killed in retribution for crop losses by local people. This study focused on determining 1) the spatial and temporal distribution of crop-raiding incidences, 2) the age, sex, and identity of crop-raiding elephants using camera-trapping and genetics, 3) the types and extent of raided crops, 4) perception of local communities towards human-elephant conflicts. But for the purpose of this paper, only results for first objective and last objective will be presented and discussed here.

MATERIALS AND METHODS

Study area

This study concentrated on the areas along the eastern side of the Udzungwa Mountains National Park (UMNP), in South-Central Tanzania. The study covered six villages: Mgudeni, Mwaya, Mang'ula A, Mang'ula B, Sole and Sonjo. Due to increased poaching in the 1960s to 1980s, elephant population size in the Udzungwa Mountains was assumed to be obliterated (Jones & Nowak, in press). But after increased protection of the park following the park's gazettement in 1992, elephant populations resuscitated. With the population of elephants increase, different groups of elephants now not only inhabit the highest altitude of the mountains, they have also expanded their range to all parts of the park and the adjacent Kilombero Nature Reserve and are often reported venturing out to raid farms that are found adjacent to park boundaries. According to the 2002 National population and housing census, Mang'ula area had a total human population of 109,866. The main economic activity in the area is agriculture. The majority of the population engages in paddy, maize and green vegetable farming while some well-to-do people engage in sugar cane growing. There is no buffer zone between the park boundary and villagers' farms, although a buffer zone was proposed by park management in 2001. Farms are located directly adjacent to the park's boundary. There is a sugar-cane plantation (about 4500 ha) which presents major challenges for the regeneration of wildlife corridors and wildlife movement because it blocks the movement of wild animals from the Udzungwas to Selous.

Data collection

The study period covered eight months from September 2010 to April 2011. Data collection was done in both dry and wet seasons.

A total of 126 raided farms were visited with 56 of these farms visited more than once. A total of 274 visits were made to farms. Raids were classified as raiding nights and raiding events. Raiding nights are nights in which raid incidences occured within the study area regardless of how many farms or villages were visited by raiders. A raiding event was an incident of crop-raiding and/or damage on a particular farm. Therefore, one or more raiding events may occur during one raiding night. The area of the farms (measured by tracking the periphery of the farm with a handheld GPS and then calculating polygon areas using Quantum GIS), type, age and quality of crops destroyed and areas destroyed were measured. An elephant damage form modified from a standard one used by the African Elephant Specialist Group (AfESG) and other HEC researchers, was used. GPS coordinates of raided farms were taken. The spatial distribution of raiding incidences was mapped in Quantum GIS to understand the influence of geography on the problem.

Five meetings with 28 leaders and farmers of the villages that are covered by the study were conducted. Initially, methodology and scope of this study, and later, results of the study and methodology for mitigation measures was presented. 180 posters were put up in the six villages to urge villagers to call the researchers in case elephant (s) had invaded their farms. Both villagers' calls and visits to the raided farms were recorded. Villagers were paid for every proved raid. Visits to farms were done in proportion to number of calls received as best as was possible. Moreover, 71 questionnaires were given to farmers whose farms were raided to acquire complimentary information on the conflicts. 29 questionnaires were not returned.

Data analysis

All statistical tests and models were conducted using R software (R Project 2.11.1). One way Chi-square test was done to test the difference in raid nights between months; spatial variation in raid nights (between villages); and to analyze farmers' perceptions on what government body should be responsible for managing wildlife outside protected areas boundaries; After normality test for monthly raiding nights (Shapiro-Wilk normality test $W= 0.8717$, $N=86$, $p=0.156$) and for monthly raid events (Shapiro-Wilk normality test $W= 0.8819$, $N=592$, $p=0.196$), Welsh two-samples t-test was used to test the difference in raid events and raid nights between wet and dry seasons.
Pearson correlation was used to test the relationship between the shortest distance from the individual farm's edge to park boundary and raid events on the farm.

RESULTS

Over the eight months of the study period, 168 reports were made by villagers on elephant raids using cellphone calls and/or short messages (SMS), and 154 visits (91.67% of all reports) were made to collect data on these raided farms following these reports (Table 1). Moreover during days between reports, researchers would visit farms to see if there are farms that were raided but were not reported. Therefore, the total number of farms that got raided is the sum of the farms visited due to farmers' reports and individual visits of the researcher and the enumerators. A summary of raiding events on farms is shown in Table 1. ix villages were monitored over the entire study period, of which two (Mgudeni and Sonjo) experienced no crop damage. Of the remaining four villages, Mang'ula B experienced 67.44% of all raiding nights (n=86), significantly more than the other villages (one-way classification chi-square: X25 = 170.165, N = 6, P <0.005;). All raids occured during night time with an exception of five days in which groups of elephants were chased into the forest by the villagers and Game Officers during day time. It should be noted here that the research station for this work is also in Mang'ula B.

Table 1. Description of crop-raiding events across villages over the study period.

Village	Total Raid events	Total farms raided	Farms raided once	Farms raided >1	Mean raids/farm	Raid nights	Crop raiding rate (Mean no. of farms raided per night)
Mgudeni	0	0	0	0	0	0	0
Mwaya	7	7	7	0	1.00	2	3.5
Mang'ula A	59	31	20	11	1.90	23	1.35
Mang'ula B	214	79	32	47	2.71	58	1.36
Sole	11	10	9	1	1.10	8	1.25
Sonjo	0	0	0	0	0	0	0

Patterns of raiding events

A total of 32 crops were damaged by elephants over the study period. There was a significant difference on the number of raids between crops (one-way classification chi-square: X231 = 0.618, N = 32, P <0.0001;).

Raiding events occurred in every month of the study period (Figure 1), throughout the dry season period (September to December) and the wet season period (January to April). There was no significant difference in crop-raids nights between the dry season (September to December) and wet season (January to April) (Shapiro-Wilk normality test W= 0.8717, N=86, P=0.156; Welsh two-samples t-test: t=1.1574, df=5.392, N=86, P=0.295) and for monthly raid events (Shapiro-Wilk normality test W= 0.8819, N=592, P=0.196; Welsh two-samples t-test: t=10.4998, df=237.61, N=592, P=0.617).

There was significant difference in raid nights between months (one-way classification chi-square: X27 = 16.767, N = 86, P <0.005; Figure 1). The highest frequency of raiding nights was in September, the peak of the dry season.

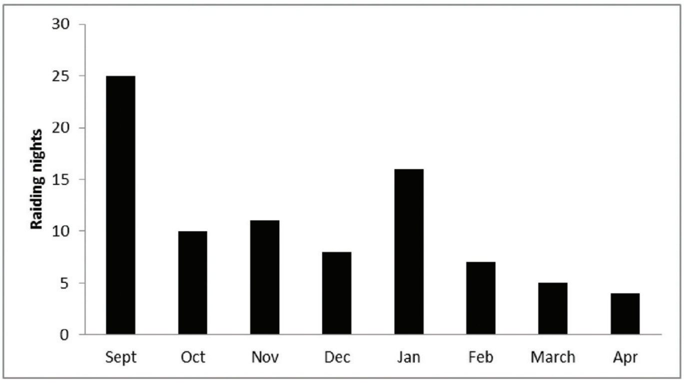

Figure 1. Distribution of raiding nights (n = 86) across the eight months of the study period

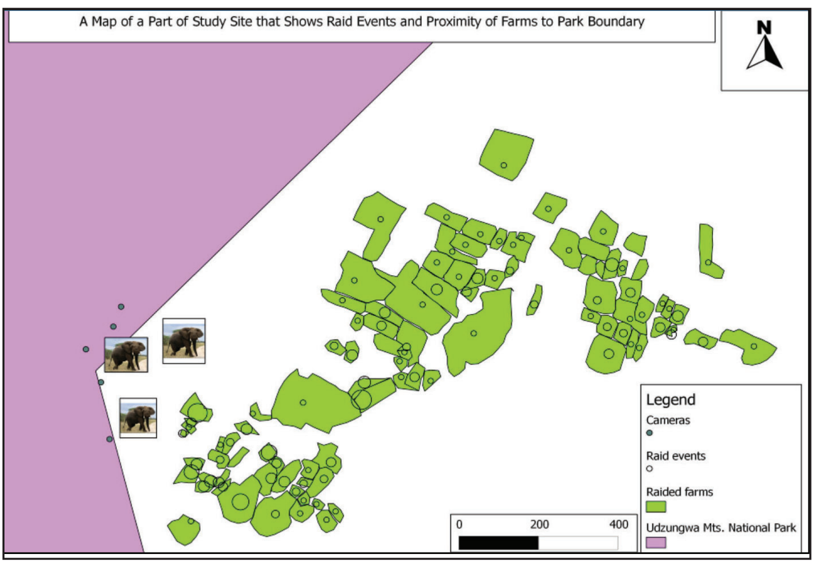

Figure 2. A section of the study area showing raid frequency and proximity of farms to park boundary. The white lines signify trails that elephants use to move out of the forest into the farms. The size of the circles represent frequency of raid events. There was no significant relationship between distance of raided farms from the park boundary and frequency of raid events (Pearson's product-moment correlation: sample estimates: cor= -0.089, t = -0.943, df = 109, P= 0.3478).

Moreover, there was significant difference in raid events between months (one-way classification chi-square: X27 = 100.389, N = 592, P <0.005) and, there was significant difference between dry and wet seasons on ratio of raid events per raid nights (one-way classification chi-square: X27 = 11.757, N = 63.034, P >0.005).

Comunity's perceptions

Results from questionnaire survey indicated that, there was no significant difference between responses from respondents about what authority should be responsible for wildlife outside the national park's boundary (one-way classification chi-square: X21 = 2.25, N = 100, P >0.005;). Farmers rated elephants as the most problematic animal out of eight known problem animals given on the questionnaire (Fig. 3).

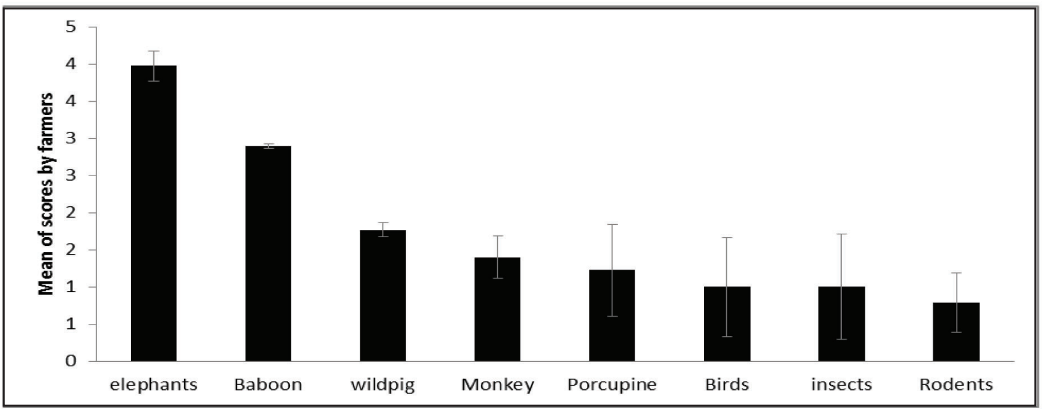

Figure 3. Farmers ranked elephants as the most destructive problem animal in the area. The bars in the graph show standard error. There was a significant correlation between ranks of crops raided and the ranks of crops that farmers perceived to be raided ((Spearman's rank correlation: rho=0.566, n=16, p=0.02). The test was done on 16 crops that appeared on both actual and perceived raided crops.

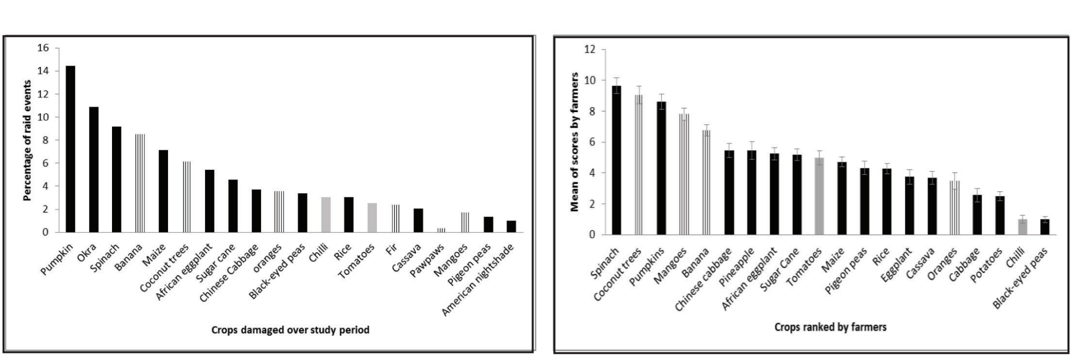

Figure 4. Ranks of crops that were actually raided by elephants (i) and those perceived (by farmers) to be raided (ii)

DISCUSSION

The interpretation of the results should be approached carefully due to the possibility of researcher bias in data collection because the number of reports decreased as distance from the research station increased. For example, it was known prior to the start of the research that Mgudeni is a village that gets raided; however, the only report of raids we received was from a mutual contact during our pilot phase. The research station was found in Mang'ula B, the village that got raided most. Both enumerators were coming from this same village so were better known by villagers and were easier to approach. In villages, especially in Tanzania, researchers and their enumerators are presumed to be from an elite class and often, villagers do not associate with them readily. This may have influenced, in one way or another, the outcome of the results. On the other hand, the principal investigator was coming from Mwaya, a village where he is well known, but only 5% of total reports received came from this village. Additionally, the meeting with village leaders before the data collection was initiated introduced all villages equally to the study and methods. To even out notification of villagers, about 180 posters (90 in each season, wet and dry) were put in each village that fell within the study area and farmers were encouraged to report the raids for which they were getting paid in 500 Tanzania Shilling phone vouchers (SMS cost about 40 TSh), therefore, there was no reason not to report the raiding incidences. Also in days when researcher and enumerators did not get reports, equal visits were paid to each village in the study area to see if there were any raid events that went unreported. So while reports and visits due to reports may have some bias, the overall patterns observed likely do not.

Farms received similar raids in all seasons with September being a month with largest number of raids overall. It should be noted though that January got significantly larger raids than any of the three dry season months with and exception of September. The raids were more regular in the dry season compared to the wet season. This may be explained by several factors. Agriculture in the study area is not influenced by rainfall. Farmers use permanent water supply flowing in rivers that comes from the rainforest-mountains. Irrigation is practiced throughout the area where elephants have been raiding. So with crops being available throughout the year, elephants'raids will tend to be evened out. Mang'ula B practices irrigation farming more than any of the six villages that we have studied. A sudden increase in raids in January may be explained by increased food between irrigated farms as the rains started. Elephant's raids are known to increase with increase in rainfall (Barnes, 2002) but then a sudden decline in raids in the successive months while rainfall increased may not be explained by the rainfall factor. A further explanatory variable is the interaction between the Game Department and elephants. On 6th February, game officers came to chase elephants back into the forest. They used rifles and shot at elephants to chase them away. Furthermore, in the middle of the same month, two elephants were killed by poachers and also two poachers were killed by elephants. It took about 21 days to start getting reports of elephant raiding crops again. And even then, elephants were not moving large distances as they were moving cautiously, and were not dropping any faeces-no dung samples were collected in February. The elephants must have been wary to leave any sign that would lead to them.

Another reason that triggered the unexpected decrease in raids during the wet season may be inundation of farms after rainfall became heavy. The land that is farmed adjacent to the park, especially in Mang'ula A, B and Mwaya is flat making it prone to floods when rainfall increases. The flood and mud make movement laborious. While wet season offers fodder of high quality and easy palatability that elephants tend to prefer (Rode et al., 2006), getting stuck in the mud waiting for farmers to come and kill you is not worth the risk.
While elephants appeared to have some preference for certain crops such as pumpkin, okra, spinach, banana, and maize, a definitive conclusion about elephants' crop-preferences could not be made. Mixed-crops farming that is practiced by almost every farmer in the study area, made it difficult to quantify areas allocated to different crops and hence impossible to know whether availability (how much of a particular crop is actually there), nutrient content, or just taste made certain crops raided more than others. Careful design of a method should be made in order to quantify availability of crops coupled with nutrient content of the crops to understand better elephant preferences for certain crops.

In of the majority of previous studies on HEC, distance that villages have to protected area has been one of the factors determining raid frequency. Crop-raiding has been seen to decline with increasing distance from the protected area (Barnes, 2002; Barnes et al., 2003; Danquah, 2003; Chiyo et al., 2005; Gunn, 2009), meaning that villages found at a relatively similar distance from protected areas would have similar crop-raid frequencies. This is not the case for villages on the eastern side of the Udzungwas. All villages are placed at relatively similar distances from the park's boundary and yet they have significantly different raid frequencies. There must be another reason to explain this situation: elephants trails/routes that they use to get out of the forest and into the forest. The Udzungwas are mountainous. Elephants need to look for an easiest way for which they can come out of the forest to raid the farms and which they can use to return quickly back to safety. The routes may be chosen due to their optimal values in case of ease to go up and down the forested hills; camouflage; shortest distance to farms; and placement (position of a trail relative to farms position) and ease of reach in case they are pursued by danger i.e., farmers. Raid location may also be related to where elephants' historic migration corridors were, but this is a difficult relationship to test given extensive sugar planting in the area since the early 1970s. When these conceptual characteristics of how elephants choose their routes are coupled with the fact that most of the mountains have areas with steep slopes that elephants may not climb or come down through, explain the reason trails of elephants may be located near each other (may be coming from different areas off the mountains but converge into these "optimum" areas). We may name this phenomenon a "Funnel Effect". This is an interesting finding and may prove important when planning for mitigation for HEC in mountainous areas.

When we did a preliminary survey of the park's boundary adjacent to farmers, we managed to locate five different trails which elephants use to get out and into the forest. The trails were close to each other. Camera traps were placed along these trails. All of these trails were leading into Mang'ula B farming area therefore elephants had to first access Mang'ula B area before moving to other villages. This may be one big reason why Mang'ula B had significantly more raids than the other villages. However we may have missed other trails (and potential camera-trapping locations) because all of seven raid nights at Mwaya and nine of all eleven raid nights that Sole had (Table 2) happened in those particular villages and nowhere else. Lack of raids in Mang'ula A and Mang'ula B, which are positioned between Mwaya and Sole, shows that those raids could not have originated from Mang'ula B trails but rather from trails found in area of the forest bordering Mwaya and Sole. These trails should be found and documented to fully analyze the movement of elephants in the landscape.

HEC and Local Communities

Farmers have shown indifferent as to who should be responsible for managing wildlife outside park's boundary. Their arguments, mostly, was that, if the responsibility continues to fall under Wildlife Division of the Central Government then the farmers should be compensated whenever crop-raids occur, and if responsibility falls under National Park Management then the park should be fenced and compensation be paid if the animals break the fence and raid the farms.

Despite the non-statistical-significance preference in responsibility, farmers showed preference towards National Park. The reason is clear, park management has resources and capacity and is in a better position to help local communities living adjacent to the park than the central government (as it is now the case) whose offices are normally found in districts headquarters, far from the problem areas (sometimes more than one hundred kilometers). It takes a long time from informing the Central government Game officers to the time they arrive to the raided area. They are often late. Even though TANAPA always set a budget yearly to combat problem animals, it lacks legal teeth to effectively control the problems. Tanzania Wildlife Policy and laws should be amended to include Tanzania National Parks as another body that may control problem animals outside park boundaries, and do so in a way that is informed by science and ethics.

Farmers ranked elephants as the worst crop raiders. Further study will determine the validity of this claim, and enable problem animals to be ranked and therefore managed accordingly, using appropriate mitigation measures. The difference between crops ranked by farmers as most raided by elephants and the ones that were ranked by actual raiding data may be attributed to the fact that each farmer was responding to the questions subjectively based on his/her experience while actual data comprises all farms raided in the area. The significant correlation between crops that are found in both lists (actual and perceived) show that farmers understand the HEC situation in their area.

Local communities and, Chili and Beehives fence

We have just finished installing beehives-chili-engine oil fence between the park and village's farms. Bees and chili have proved to be good deterrent of elephants. We are now monitoring the fence; results will be published later with other data.

CONCLUSION

Relative distance between villages and protected area boundaries is not always an important factor in understanding HEC. The identification of optimally placed elephant trails/routes ("Funnel Effect") is also important when analyzing spatial variation in crop-raiding incidence between villages in mountainous settings. Apart from crop availability and seasons, human factors play a big role in understanding HEC.

ACKNOWLEDGMENT

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HUMAN RESOURCE DEMAND AND BIODIVERSITY CONSERVATION AT UDZUNGWA MOUNTAINS NATIONAL PARK, TANZANIA: CHALLENGES AND OPPORTUNITIES THROUGH COMMUNITY DESIGN

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ABSTRACT

Home to remarkable amounts of biological diversity, Tanzania also is a nation of more than 42 million people, many involved in some sort of agriculture or other form of extractive activity that threatens natural habitat and biodiversity conservation. Amid widespread human presence, the Tanzanian government manages nature in a system of protected areas that includes forest reserves, game reserves, national parks, Ramsar sites, village forest reserves, and wildlife management areas. This paper explores the human context of protected areas in Tanzania through analyses employing geographic information system technology, both to gain a better sense of possible threats to these areas from local peoples and to understand the impacts that various levels of restricted use in these areas have on nearby human settlement. Examining data from the most recent available census of population and housing (2002) yields insights on the socioeconomic context a of different protected area categories a decade ago. Results indicate possible pressure that humans can have on Tanzanian reserves, presenting key challenges to biodiversity conservation in the 21st century—namely how to manage natural habitat and associated species in a nation increasingly affected by human use and economic development. Considering potential impacts of climate change, and its dual effects on the human and natural environments, reveals likely future impacts in the form of expanding agricultural activity and changing human settlement that will threaten people and nature alike.

Key words: *Protected areas, biodiversity conservation, human demographics, climate change*

INTRODUCTION

Biodiversity is under threat globally, the rate of species loss reaching levels rarely equaled in the entire history of our planet (Pimm et al., 2008). As researchers, government agencies, non-governmental organizations, and others examine the disappearance of biological diversity, they focus on areas that are priorities for maintaining species and ecosystems (Brooks et al., 2006). In the quest to define priorities for conservation efforts, certain nations emerge as particularly important for containing a disproportional amount of our planet's biological heritage. Tanzania is one such country, home to portions of two biodiversity hotspots (Mittermeier et al., 2004a), part of one biodiversity wilderness area (Mittermeier et al., 2003), and portions of nine of the Global 200 ecoregions (Olson and Dinerstein, 1998).

Tanzania shares important characteristics with many other nations important to conserving biodiversity. It lies in the tropics, in the portion of Earth where many of the plant and animal species on our planet exist. And it is a developing country, a nation where much of the population has low income, limited access to education, and poor health, as defined by the United Nations Human Development Index (United Nations Development Programme, 2012). The development status of Tanzania is particularly important to conservation, both because of the limited economic alternatives available to much of its population and because Tanzania, as is the case with many developing countries, is witnessing considerable demographic growth. Increasing demand, amidst an economic system dominated by small-scale extractive activities, places pressure on the very natural environment that must support non-human species as well. In such cases, the human presence near important locations of biodiversity creates the conditions for degradation or loss of habitat, loss of key species, or both in the absence of actions designed to maintain biodiversity.

This paper examines the human context near protected areas in Tanzania, localities most important for conserving biological diversity in this East African nation. The focus primarily is on human population near protected areas, as a rough indicator of likely human pressure. The study employs data from the most recent available census of population and housing, in 2002, estimating the number of people living within 10 km of each protected area. The paper considers six main types of reserves, estimating population in close proximity for each category of protected area as well as for individual reserves. It also looks at the nature of the human presence in terms of level of economic activity, number of people engaged in farming, and number of households relying on charcoal or firewood as their main source of domestic fuel—all indicators of potential pressure on reserves. The paper closes with recommendations for prioritizing conservation efforts, by protected area type as well as by individual protected area.

METHODS

Tanzania contains a remarkable amount of biological diversity. Statistics now nearly a decade old indicate the presence of more than 10,000 higher plant species, 316 species of mammals, and 229 species of breeding birds (World Resources Institute, 2003). Conservationists have translated these figures into conservation priorities that lie at least partially in Tanzania. For instance, the two biodiversity hotspots alluded to above—the Eastern Afromontane and the Coastal Forests of East Africa—each contain extremely high numbers of total species, many of them endemic to each region (Mittermeier et al., 2004b):

- Coastal Forests of East Africa: 4,000 plant species, 198 mammals, 636 birds, 250 reptiles, 102 amphibians, and 219 freshwater fishes.
- Eastern Afromontane: 7,598 plant species, 490 mammals, 1,325 birds, 347 reptiles, 285 amphibians, and 893 freshwater fishes.

Increasingly, Tanzania relies on protected areas to help conserve its biodiversity. Protected areas are locations on land or in the ocean intended to protect through legal or other means biological diversity, natural resources, or cultural resources (World Congress on National Parks and Protected Areas, 1992). Tanzania is particularly well covered by protected areas, the nearly 800 such localities in 2010 covering 39.6% of its land area (World Database on Protected Areas, 2010) (Figure 1). Tanzania contains 14 different types of protected areas: conservation areas, forest reserves, game controlled areas, game reserves, marine parks, marine reserves, marine sanctuaries and forest reserves, national parks, nature reserves, state forest reserves, village forest reserves, Ramsar sites, village forest reserves, and World Heritage Convention sites.

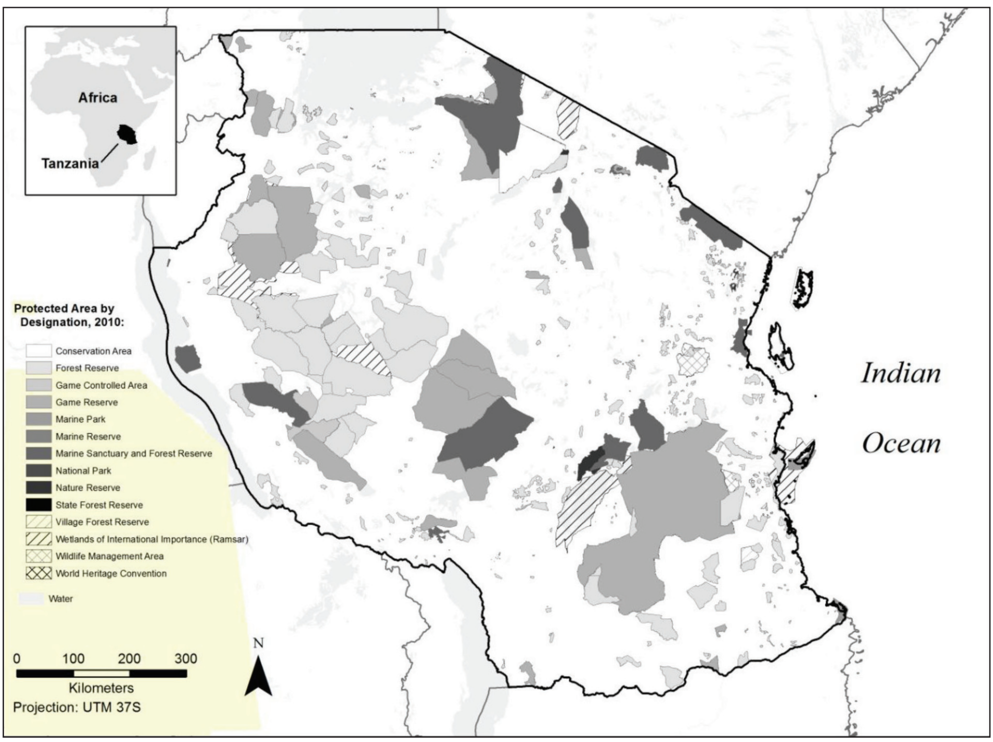


Figure 1: Protected areas in Tanzania

TAn examination of land cover in Tanzania reveals the importance of protected areas to the conservation of nature. Focusing on land cover designations from the European Space Agency classification for land cover and land use in Tanzania (European Space Agency, 2008) reveals that Tanzania is a combination of natural and modified habitat, the latter often agricultural (frequently combined with natural land cover in some sort of mosaic) (Table 1). Defined at a 300 m resolution, more than 75% of the country is natural habitat of one form or another, with forest (broadly defined) and woodland dominating. However, nearly one-fourth of the country consists of agricultural land use/land cover, a number consistent with the large amount of crop production that occurs in Tanzania. Recognizing the potential of agricultural activity for disruption of natural ecosystems, coupled with the notion that many instances of the small-scale agriculture that characterizes much of Tanzania likely appears as some form of natural habitat, protected areas emerge as essential to the conservation of biological diversity in this nation.

The distribution of land use and land cover in Tanzania, and associated pressures on biodiversity conservation, are a consequence the geographic arrangement of people, and vice versa. In 2011, Tanzania contained an estimated 43.7 million, having increased from 34 million recorded by the most recent census in 2002 (National Bureau of Statistics, n.d.; World Bank, 2011). Using information on population distribution in 2002, based on census data in geographic information system (GIS) format, provides a sense of the spatial arrangement of population. The distribution of population was fairly sparse, with occasional concentrations but few high densities (Figure 2). Although one can map population density with some accuracy, researchers currently do not know what density begins to compromise biodiversity, though empirical research in other areas suggest that it may be as low as 10/km2 (Gorenflo, 2011). If this is so, the situation concerning the distribution of human population near protected areas in Tanzania is quite concerning.

The distribution of land use and land cover in Tanzania, and associated pressures on biodiversity conservation, are a consequence the geographic arrangement of people, and vice versa. In 2011, Tanzania contained an estimated 43.7 million, having increased from 34 million recorded by the most recent census in 2002 (National Bureau of Statistics, n.d.; World Bank, 2011). Using information on population distribution in 2002, based on census data in geographic information system (GIS) format, provides a sense of the spatial arrangement of population. The distribution of population was fairly sparse, with occasional concentrations but few high densities (Figure 2). Although one can map population density with some accuracy, researchers currently do not know what density begins to compromise biodiversity, though empirical research in other areas suggest that it may be as low as 10/km2 (Gorenflo, 2011). If this is so, the situation concerning the distribution of human population near protected areas in Tanzania is quite concerning.

Table 1. Land cover in Tanzania, according to the European Space Agency dataset for 2005

Category	Area (km^2)	Percent of Total
Total	966,323	100.00
Broadleaved evergreen tree cover	11,728	1.21
Broadleaved deciduous tree cover	310,501	32.13
Regularly flooded tree cover	371	0.04
Tree cover and other natural veg. mosaic	670	0.07
Shrub cover	192,249	19.89
Herbaceous cover	146,895	15.20
Sparse herbaceous/sparse shrub cover	3,680	0.38
Regularly flooded shrub or herbaceous	2,232	0.23
Cultivated and managed	231,976	24.01
Cropland mosaic	101	0.01
Bare areas	249	0.03
Water bodies	65,473	6.78
Artificial surfaces and associated	198	0.02

Source: GIS calculations based on European Space Agency, 2008

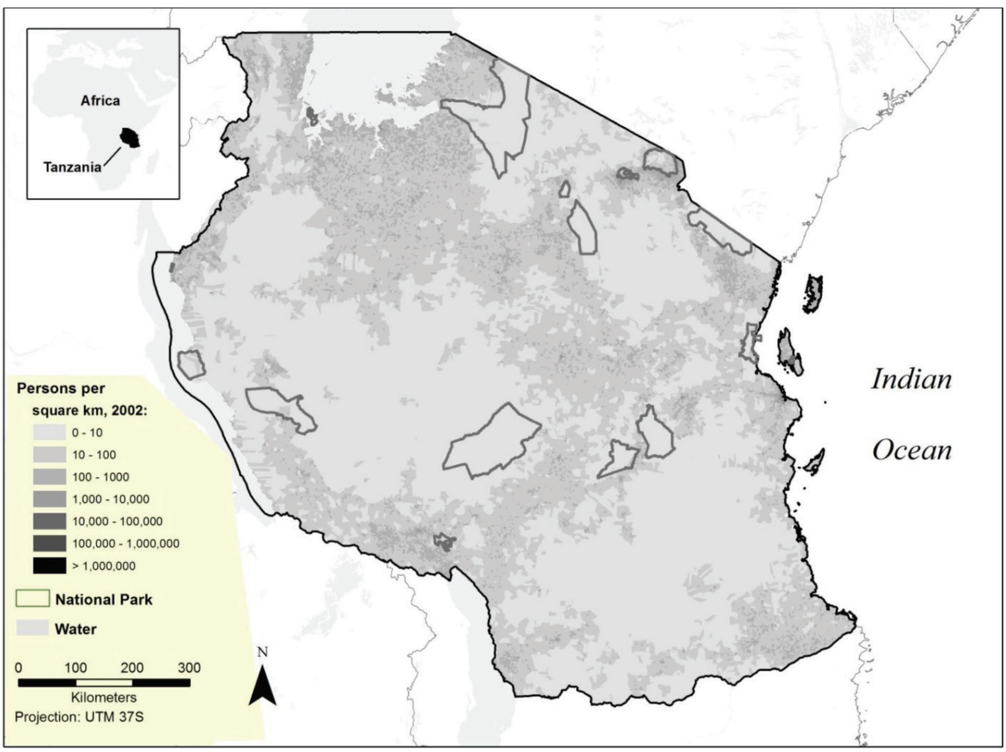


Figure 2: Population density in Tanzania in 2002 with respect to national parks (note: other protected area types not shown due to resulting complexity of map; for general consideration of other protected area types, compare this figure to Figure 1)

A closer examination of one protected area provides a sense of how complicated the situation can be. Udzungwa Mountains National Park is one of the newest national parks in Tanzania. Gazetted in 1992 and covering about 1,900 km2 in the Eastern Arc Mountains immediately west of the fertile Kilombero Valley, despite little indication at a coarse scale of human impacts considerable human settlement and converted habitat occurs in the vicinity of the park (Figure 3). Much of the converted habitat is in the form of agriculture, consistent with statistics for the entire country, though in the case of Udzungwa in the immediate vicinity of this one protected area.

Using GIS technology, one can estimate the number of people who lived within 10 km of protected areas in 2002. Data from 2002 are the most recent available in GIS format, and although nearly one decade old as this paper is written they provide a sense of the level of challenge facing conservation in this East African nation. One can consider10 km as a rough measure of proximity that would allow people, under most conditions, to travel to a PA, use resources, and return home in a single day. Here the focus is on six main types of protected areas, areas, accounting for 96.3% of the total number of reserves and 77.7% of the total area protected in Tanzania (World Database on Protected Areas, 2010): forest reserves, game reserves, national parks, Ramsar sites village forest reserves, and wildlife management areas.

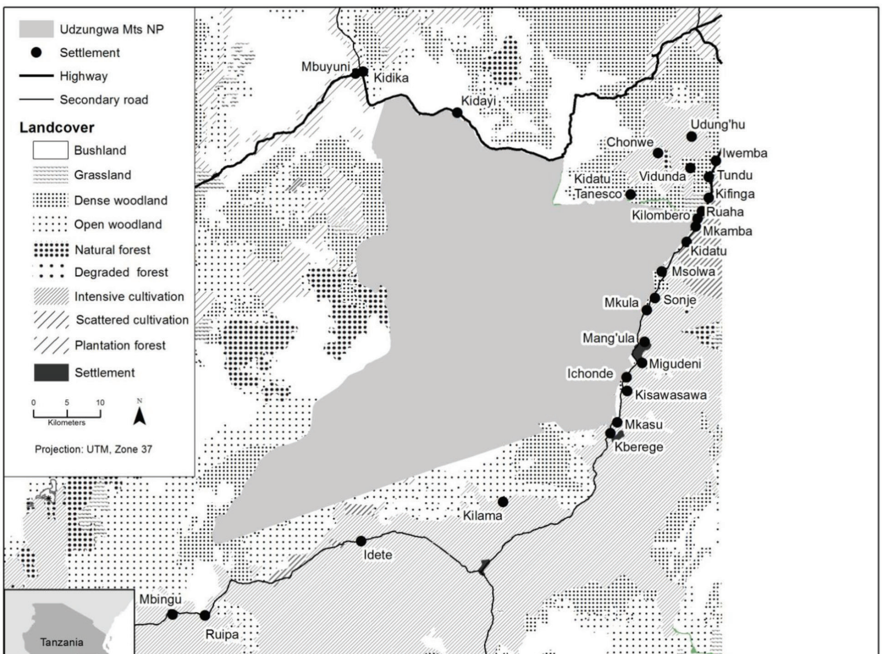


Figure 3: Human settlement and land cover/land use in the vicinity of Udzungwa Mountains National Park

RESULTS

Examining the 2002 census data indicates a remarkably large number of people living within 10 km of the six types of protected areas examined in this study (Table 2). A total of 19.3 million people lived near the protected areas considered, some 57% of the entire national population in 2002. The greatest number of people, in the second highest densities, lived near forest reserves, in part reflecting the large number of forest reserves as well as their location in a variety of settings. Game reserves and national parks each had in excess of 2.1 million people living in close proximity in 2002, the latter registering the highest densities of the six types examined. The reason for the relatively high densities of human settlement in proximity of national parks is unclear, but may in some cases reflect perceived opportunities from close geographic association. The national parks with the highest densities were Kilimanjaro and Arusha, both receiving large numbers of visitors and, potentially, experiencing benefits from the high amount of tourism. Other types of protected areas had much lower human presence and population density within 10 km of their borders, though the numbers for Ramsar sites and village forest reserves still indicate many people within close proximity.

Table 2. Human Population and Population Density within 10 km of selected types of protected area: 2002

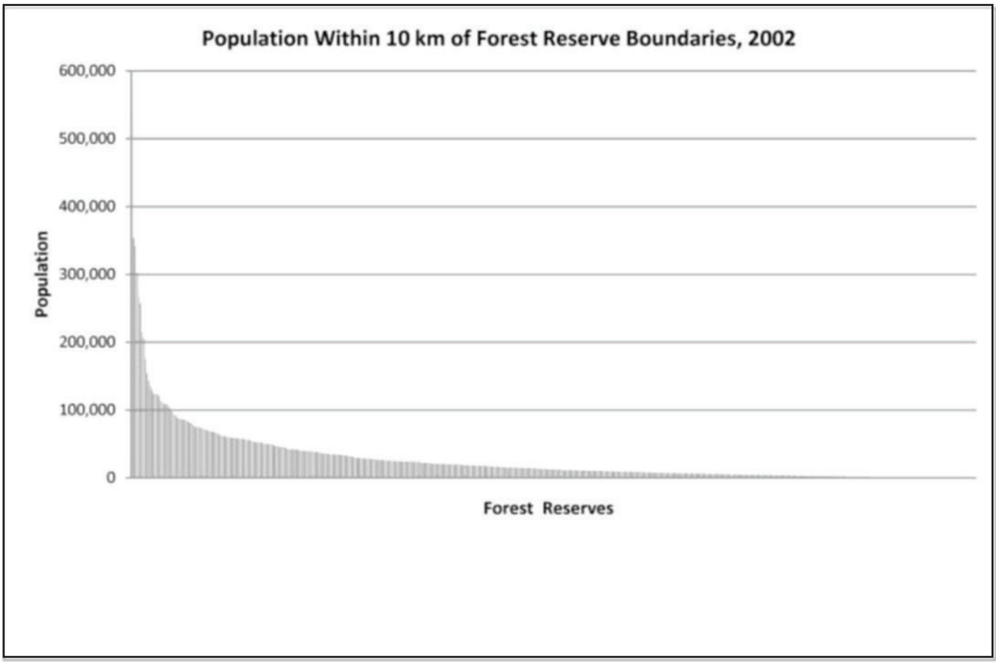
Protected Area Type	Population within 10 km	Population Density within 10 km [a]
Total [b]	19,309,199	39.3
Forest Reserve	13,939,992	41.2
Game Reserve	2,383,186	33.2
National Park	2,194,117	56.7
Ramsar Site	488,577	21.3
Village Forest Reserve	242,775	16.6
Wildlife Management Area	60,552	11.1

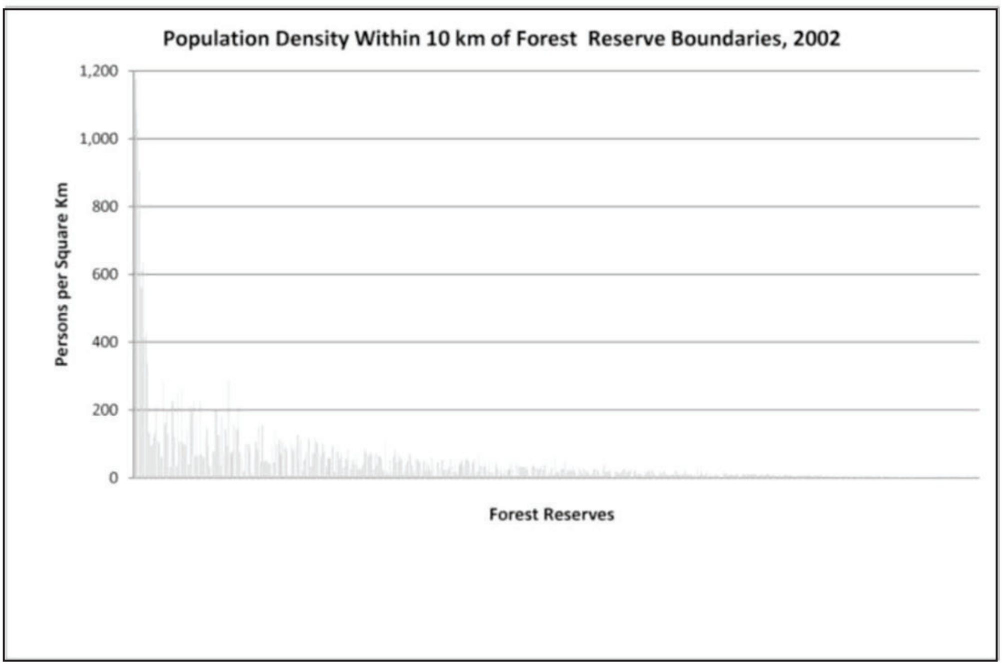
a: Persons/km2
b: Rows may not sum to totals as some 10 km buffers overlap with others
Source: Based on GIS analysis of 2002 census data (National Bureau of Statistics, n.d.) with respect to protected area boundaries (World Database on Protected Areas, 2010)

It is possible to examine demographic characteristics of each type of protected area as well. Figure 4 shows results for each of the six types of protected area. Forest reserves, by far the most numerous protected area type, also had the largest number of people living within 10 km of their boundaries. Presumably maintaining any type of conservation function of such sites, in the face of high human demand in close proximity and with limited management staff to maintain their conservation function, will be an enormous challenge. Population living near other types of protected areas varied, and as their numbers were not so great the 2002 population near each individual area can be shown on the bar charts in Figure 4.

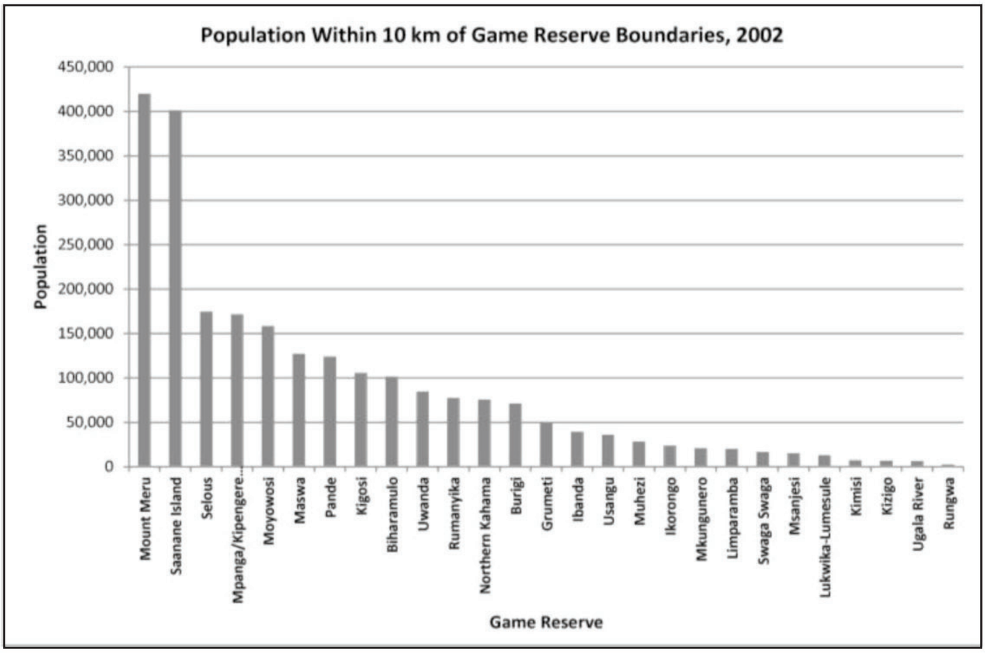
The bar charts in Figure 4 are informative, though one needs to exercise care in interpreting them. For instance, often it is the combination of total population and density that reveals possible concerns, absolute population indicating the scale of human demand and density adjusting for different sized areas within a 10 km-wide buffer. These two measures in a sense represent magnitude vs. intensity, respectively. The Selous Game Reserve provides a good example of the complementary insights from the two measures, the nearly 175,000 people living within 10 km of the reserve's boundary in 2002 representing only about 13.6 persons/km2 due to the enormous size of its geographic extent. Another consideration is that population rarely is distributed uniformly, instead often occurring in denser concentrations, and it is these concentrations that generate the greatest demand, and hence likely the greatest pressure on a given protected area. Because limitations of space preclude presentation of maps showing population distributions, I currently am considering development of a web-based utility that would provide protected area managers in Tanzania with cartographic details of demographic distributions in the vicinity of their parks.

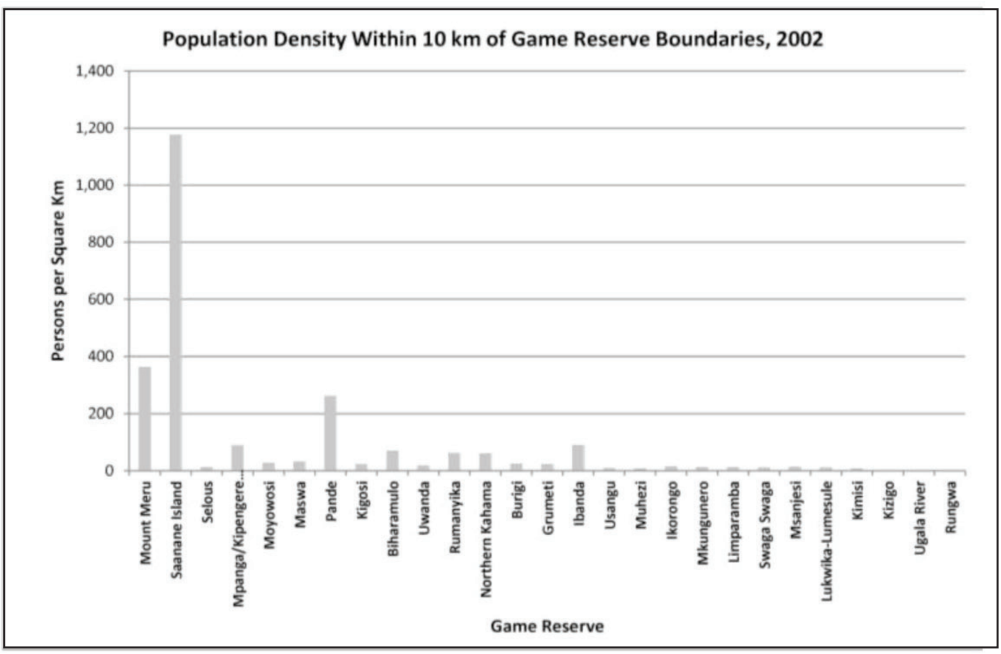
The presence of large numbers of people in the vicinity of protected areas in Tanzania is a concern because of the nature of human activity throughout much of the country. Largely rural, the Tanzanian population relies heavily on local extraction (or production) of necessary resources. For example, 72.3% of the population that reported occupation in 2002 listed farming (based on analysis of the 2002 census data—see National Bureau of Statistics, 2006). Economies often are mixed with a dual emphasis on subsistence, usually emphasizing agriculture, supplemented by activities that generate a small amount of wages, so people live close to the land and extract what they need from it. And a large percentage of households in Tanzania (94.9%) relied on charcoal and wood for fuel in 2002, for domestic use (e.g., cooking) and often for other activities, such as brick-making and local brewing (Nyundo et al., 2006; World Bank, 2009). Such economic patterns and cultural behavior place people in direct competition with other species for necessary resources, and suggest that large numbers of people in the vicinity of a protected area can mean pressure on that protected area.


Population Within 10 km of Forest Reserve Boundaries, 2002
600,000
500,000
400,000
300,000
200,000
100,000
0
Population
Forest Reserves

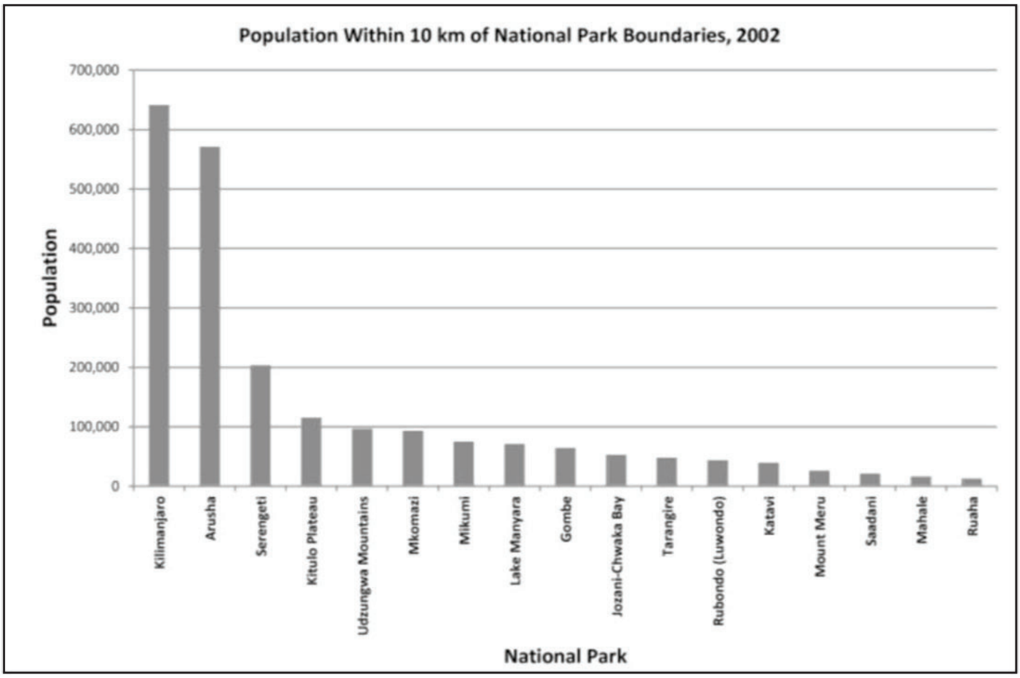

Population Density Within 10 km of Forest Reserve Boundaries, 2002
1,200
1,000
800
600
400
200
0
Persons per Square Km
Forest Reserves

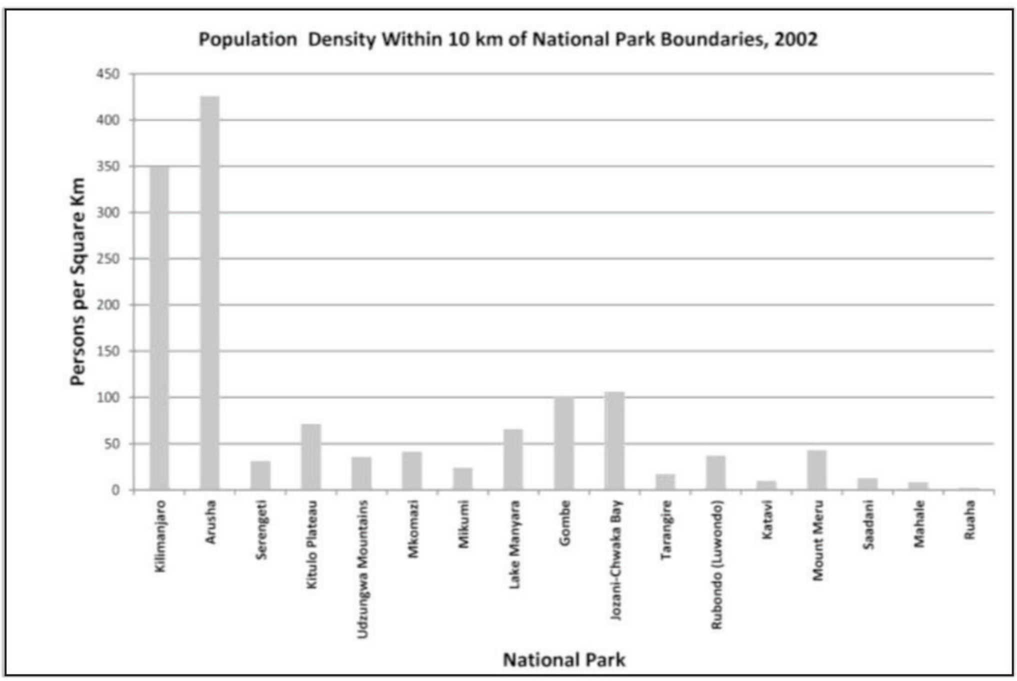
a


Population Within 10 km of Game Reserve Boundaries, 2002
Population
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Mount Meru
Saanane Island
Selous
Mpanga/Kipengere...
Moyowosi
Maswa
Pande
Kigosi
Biharamulo
Uwanda
Rumanyika
Northern Kahama
Burigi
Grumeti
Ibanda
Usangu
Muhezi
Ikorongo
Mkungunero
Limparamba
Swaga Swaga
Msanjesi
Lukwika-Lumesule
Kimisi
Kizigo
Ugala River
Rungwa
Game Reserve

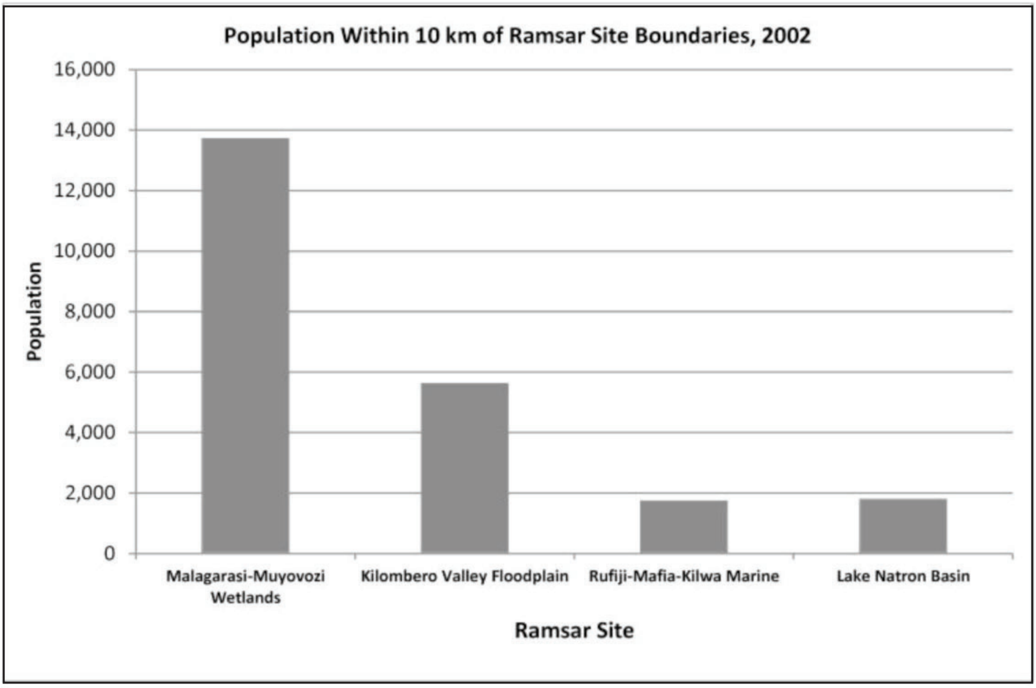

Population Density Within 10 km of Game Reserve Boundaries, 2002
Persons per Square Km
1,400
1,200
1,000
800
600
400
200
0
Mount Meru
Saanane Island
Selous
Mpanga/Kipengere...
Moyowosi
Maswa
Pande
Kigosi
Biharamulo
Uwanda
Rumanyika
Northern Kahama
Burigi
Grumeti
Ibanda
Usangu
Muhezi
Ikorongo
Mkungunero
Limparamba
Swaga Swaga
Msanjesi
Lukwika-Lumesule
Kimisi
Kizigo
Ugala River
Rungwa
Game Reserve

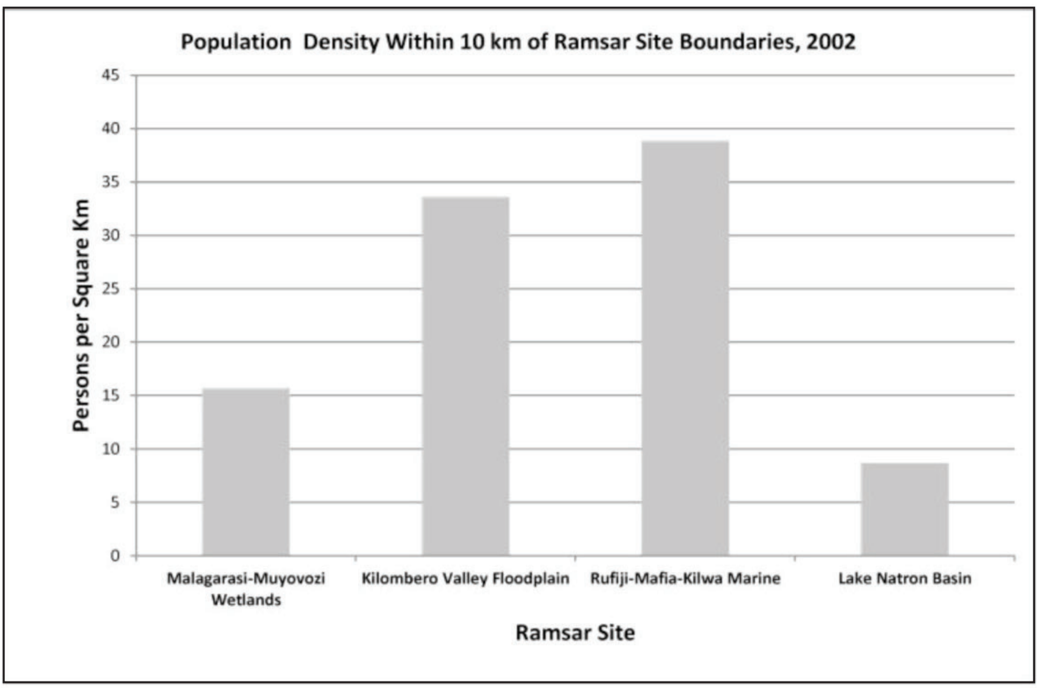
b


Population Within 10 km of National Park Boundaries, 2002
Population
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Kilimanjaro
Arusha
Serengeti
Kitulo Plateau
Udzungwa Mountains
Mkomazi
Mikumi
Lake Manyara
Gombe
Jozani-Chwaka Bay
Tarangire
Rubondo (Luwondo)
Katavi
Mount Meru
Saadani
Mahale
Ruaha
National Park

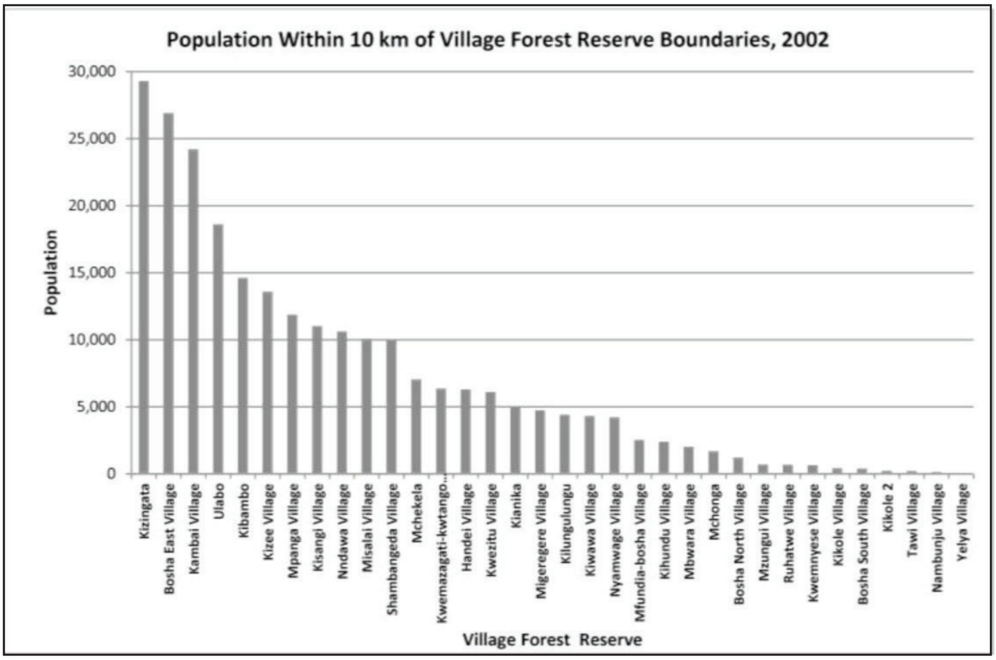

Population Density Within 10 km of National Park Boundaries, 2002
Persons per Square Km
450
400
350
300
250
200
150
100
50
0
Kilimanjaro
Arusha
Serengeti
Kitulo Plateau
Udzungwa Mountains
Mkomazi
Mikumi
Lake Manyara
Gombe
Jozani-Chwaka Bay
Tarangire
Rubondo (Luwondo)
Katavi
Mount Meru
Saadani
Mahale
Ruaha
National Park

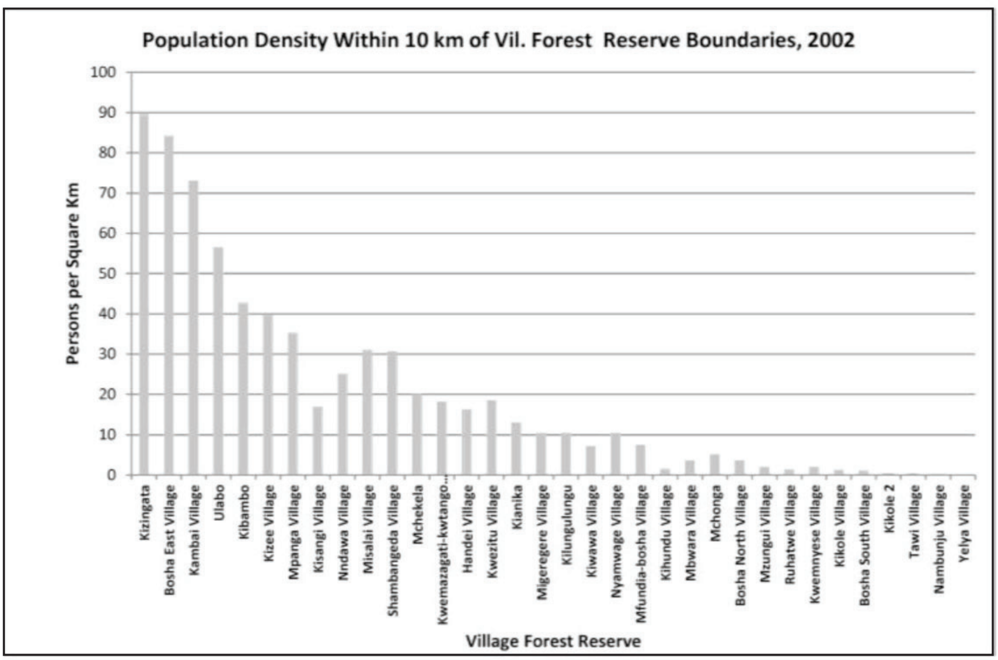
c


Population Within 10 km of Ramsar Site Boundaries, 2002
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Population
Malagarasi-Muyovozi Wetlands
Kilombero Valley Floodplain
Rufiji-Mafia-Kilwa Marine
Lake Natron Basin
Ramsar Site


Population Density Within 10 km of Ramsar Site Boundaries, 2002
45
40
35
30
25
20
15
10
5
0
Persons per Square Km
Malagarasi-Muyovozi Wetlands
Kilombero Valley Floodplain
Rufiji-Mafia-Kilwa Marine
Lake Natron Basin
Ramsar Site

d


Population Within 10 km of Village Forest Reserve Boundaries, 2002
Population
30,000
25,000
20,000
15,000
10,000
5,000
0
Kizingata
Bosha East Village
Kambai Village
Ulabo
Kibambo
Kizee Village
Mpanga Village
Kisangi Village
Nndawa Village
Misalai Village
Shambangeda Village
Mchekela
Kwemazagati-kwtango...
Handei Village
Kwezitu Village
Kianika
Migeregere Village
Kilungulungu
Kiwawa Village
Nyamwage Village
Mfundia-bosha Village
Kihundu Village
Mbwara Village
Mchonga
Bosha North Village
Mzungui Village
Ruhatwe Village
Kwemnyese Village
Kikole Village
Bosha South Village
Kikole 2
Tawi Village
Nambunju Village
Yelya Village
Village Forest Reserve


Population Density Within 10 km of Vil. Forest Reserve Boundaries, 2002
Persons per Square Km
100
90
80
70
60
50
40
30
20
10
0
Kizingata
Bosha East Village
Kambai Village
Ulabo
Kibambo
Kizee Village
Mpanga Village
Kisangi Village
Nndawa Village
Misalai Village
Shambangeda Village
Mchekela
Kwemazagati-kwtango...
Handei Village
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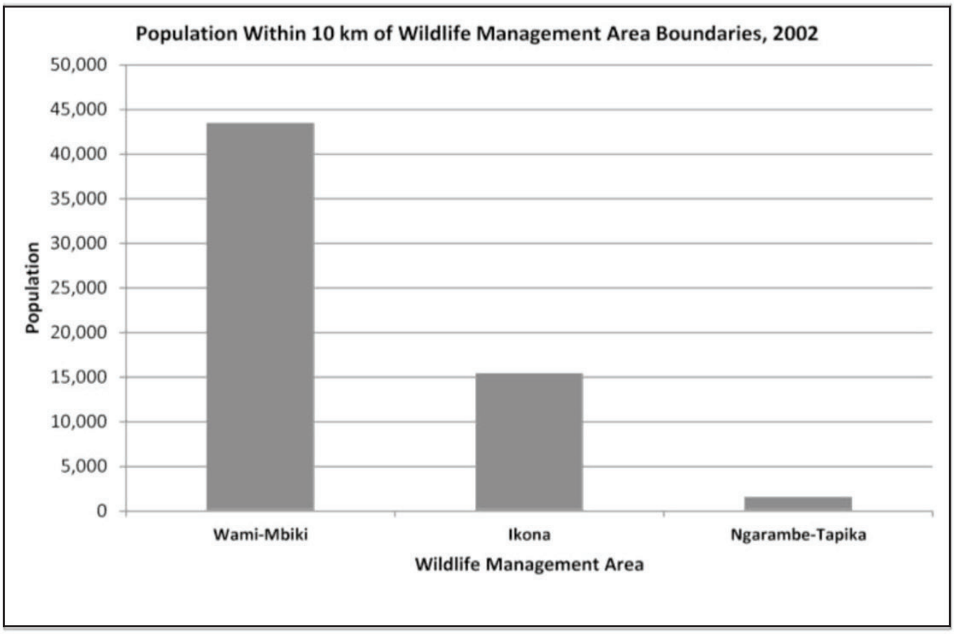

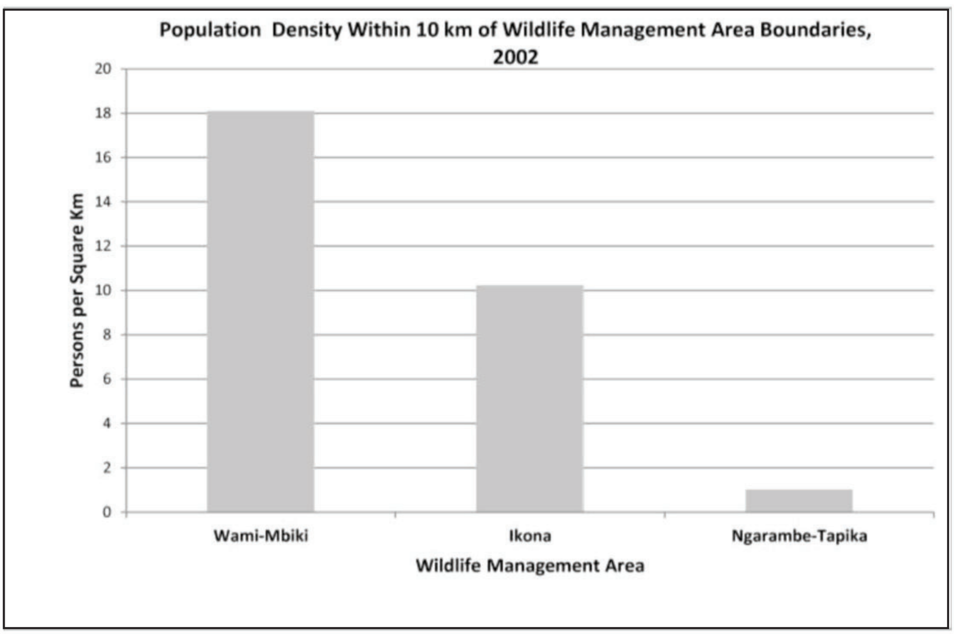

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Figure 4: Population and population density within 10 km of specific types of protected areas: a) forest reserves; b) game reserves; c) national parks; d) Ramsar sites; e) village forest reserves; and f) wildlife management areas

DISCUSSION AND RECOMMENDATIONS

Conservation of biological diversity throughout the world increasingly occurs amid a large human presence and considerable human use, both often generating substantial impacts on the natural world. Geographic proximity does not always tell the entire story. For instance, in some situations commercial agriculture occurs in regions with fairly sparse populations, responding to more distant demands, though it generates massive adverse impacts on the environment. Similarly, charcoal production often serves urban demands, yet can occur in sparsely populated areas where forests remain (World Bank, 2009). Thus, many local impacts in rural settings are responses to more distant urban demands for resources. Nevertheless, in Tanzania there is considerable local demand near protected areas as well. Resource extraction to support rural populations often occurs in close proximity to those populations, in the absence of extensive distribution systems and the ability to finance such systems, making the occurrence of settlement near reserves a good indicator of pressure regardless of the level of more distant demand.

What one finds in Tanzania is a large number of people living close to protected areas. Although much of the nation has some sort of protected status, the contribution of protected areas to biodiversity conservation in such situations may at worst be compromised, and at best require considerable effort to guarantee protection. Results in this study indicate that forest reserves face enormous local pressures—large numbers of people, often in high densities, near many of current reserves in this category. Forest reserves generally are accorded lower protection than other types of protected areas in Tanzania, and even in cases lacking dense local settlement impacts can be high (Rovero et al., 2005), suggesting that in many cases the analysis presented here underestimates impacts on such sites. In all, despite the large number of forest reserves the contribution of this category of sites to biodiversity conservation may be much lower than first impression.

Other types of protected areas likely contribute more to maintaining biological diversity, though with certain caveats. National parks, for instance, receive the highest amount of protection of any category of protected area in Tanzania. Yet some parks, such as Kilimanjaro and Arusha national parks, have tens of thousands of people living near their borders, often in reasonably high densities. There is a need to focus particularly on protection strategies in such localities. At a minimum, the effective removal of buffer zones from the conservation equation will reduce the effectiveness of the parks. In the worst case, the demands of local people will reduce key resources, biological diversity, or both in the parks, greatly compromising their contributions to biodiversity conservation.

In the presence of high biological diversity, two general strategies emerge (depending on conservation priorities): aggressively protect conservation priorities, or surrender protection to focus on other localities.

In the case of the former, if a locality is essential to conservation in Tanzania, steps must be taken to understand and somehow meet human demand, directly or indirectly assisting local communities to meet their needs without inflicting damage on the locality in question. In the case of the second strategy, when conservation costs exceed benefits and localities are not essential to carefully defined conservation objectives, the most practical option may be to remove protection (at least of biodiversity) of some localities in favor of others with more potential for success. National parks and, to a certain extent Ramsar sites, wildlife management areas, and (possibly) game reserves, are classes of protected areas that may fall under the first strategy, depending on the contribution of individual localities to biodiversity conservation goals. Forest reserves, and possibly village forest reserves, may fall under the latter, the former because of the huge volume of human demand located in close proximity and the latter because of decentralized management which makes overall coordination of conservation efforts difficult or impossible.

Climate change in Tanzania has great potential to complicate an already difficult situation in the vicinity of protected areas. Although current methods do not support the projection of local conditions, anticipated changes in East Africa include higher temperatures, increased precipitation during rainy seasons, extended dry seasons, increased unpredictability of wet and dry seasons, and more frequent and intense severe weather events (Case, 2006). Such changes will have implications for all Tanzanians, in the case of subsistence agriculturalists and pastoralists greatly decreasing food security as crop production and animal husbandry become more tenuous endeavors. For people living near protected areas, one strategy in the face of uncertain food supply may be to look to other resources, including the plants and animals present in various types of nearby reserves. Managers of the various protected areas will need to be mindful of such increased human pressures, with long-term solutions requiring broad strategies that include implementation of means to help meet basic human demands in addition to the protection of natural resources.

Tanzanian population is growing, increasing by about 9 million (more than 28%) between the census in 2002 and estimates for July 2011 (World Bank, 2011). With growing population comes growing demand, and escalating pressure on natural resources and natural habitat. Conservation increasingly requires planning, actions purposefully aimed towards conserving biological diversity. In Tanzania, this may well require a national strategy that incorporates conservation priorities, on the one hand, and human impacts on the other. Tanzania, as with other countries, cannot conserve everything and still provide for its people. However, with proper planning and effective conservation actions built upon that planning, it may be possible to conserve much to represent the diversity of life in this nation of remarkable biological resources.

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TOWARDS COMMERCIALIZATION AND SUSTAINABLE UTILIZATION OF *SYNADENIUM GLAUCESCENS* IN IRINGA REGION, TANZANIA

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ABSTRACT

Climate change is increasingly affecting both animal and human health by altering the geographic range and seasonality of causative agents and disease risk factors. In the tropical developing countries, diseases pose big challenges especially in rural areas where health care system offers limited services to the majority of the population. Due to lack or limited access to health services, majority of the people have opted for traditional treatments using plants. Synadenium glaucescens, a wild medicinal plant which is scarcely domesticated, is among plants highly utilized in Tanzania. The plant is reported to be endangered in northern Tanzania due to high exploitation by the communities around Usambara Mountains. Findings from the on-going research have shown high level of awareness about its potential, and extent of exploitation. The plant extracts have demonstrated high antiviral, antibacterial and anti-parasitic properties. As a strategy towards sustainable commercial utilization, two patents have been approved; attempts towards domestication; and other chemistry approaches are underway with promising results. Further studies of the plant will create more opportunity for the exploitation of the plant at commercial level in a sustainable manner. Domestication and synthetic chemistry approaches will reduce its harvest in the wild, and enhance carbon sequestration as mitigation strategy of climate change.

Key words: *Climate change, Vegetation, Medicinal plants, ethnobotany, Synadenium glaucescens*

INTRODUCTION

Climate change has become increasingly recognized as one of the greatest challenges to all life forms by causing noticeable effects on the life cycles and distributions of the world's vegetation. Climate change is already having an impact on the dynamics of African biomes and its rich biodiversity, although species composition and diversity is expected to change due to individual species response to climatic conditions1. Besides changes in plant phonology, climate change influences the shift in species distribution, loss of habitat and alters medicinal plants composition and abundance and their secondary metabolite production . Africa contains about one-fifth of all known species of plants, which compose some of the world's most diverse and biologically important ecosystems such as savannahs and tropical forests . In sub-Saharan Africa, which includes parts of East Africa, several ecosystems, particularly grass and shrub savannahs, are shown to be highly sensitive to short-term availability of water due to climate variability . According to IUCN data (2003), Tanzania has 10,008 known species of higher plants including endemic and non endemic, out of which 235 (2.9%) are threatened. Medicinal plants are not immune to the effects of climate change. Toping up the high exploitation rate by the communities renders them too vulnerable to extinction especially those which are endemic to geographic regions or ecosystems vulnerable to climate change.

Climate change is increasingly affecting both animal and human health by altering the geographic range and seasonality of causative agents and disease risk factors. Scientist have already established the relation that climate change has been exacerbating the occurrence and intensity of some disease outbreaks and perhaps increase the spread of diseases such as Malaria. In Tanzania malaria accounted to 24.4% to 48.9% morbidity across Tanzania ; for example: there is a well-established correlation between climate variability and extreme weather such as high temperatures and intense rainfall events and malaria in east Africa higherlands, Tanzania in particular. Scientists have found a correlation between rainfall and unusually high maximum temperatures and the number of malaria cases and Rift Valley Fever outbreaks , & . Some parts of Tanzania especially in the higherlands (Mbeya, Iringa, Njombe and Arusha) are experiencing a spread of malaria in populations that had not previously been. Climate change challenges the millennium Development goals (MDG) achievement in general and MDGs 4,5 and 6 in particular in Tanzania by facilitating the disparities persist, between districts and regions, age, urban versus rural areas, and by wealth status & . Rural communities and, in particular poor people with livelihoods that are highly dependent on ecosystem services and products are more vulnerable to these changes. In rural areas where health care system offers limited services to the majority of the population diseases pose big challenges. Due to lack or limited access to health services, the majority of people have opted for traditional treatments using plants.

Medicinal plants are essential natural resource which constitutes one of the potential sources of new products and bioactive compounds for drug development. In spite of the advent of the modern high throughput drug discovery and screening techniques, traditional knowledge of medicinal plants has always guided the search for new cures by providing clues to the discovery of valuable drugs . A study by Farnsworth (1988) indicates that of 119 known useful plant-derived drugs, 74% of the chemical compounds used as drugs have the same or related use as the plants from which they were derived. These chemicals have played a role in the commercial development of new products for medical, cosmetics, pesticide and other purposes since they are considered more environmentally friendly and human safe as they easily biodegrade in the environment. It is estimated that 60% of the world population and 80% of the population of developing countries rely on traditional medicine, mostly plant drugs, for their primary health care needs (WHO). In Tanzania over 60% of health seeking population have a traditional healer as the first point of contact while it is estimated that 80% of Tanzania population comprising rural and urban depend on traditional medicine for their primary health care. The ration of traditional health practitioner/ peoples population is 1:400,while that of doctors/patients is 1:20,000 of this great work force of traditional health practice, the practice constitute the main part of their daily earning. People over the centuries, have developed a wide variety of technologies with due regard to the nature and the ecosystem13. Exploration of medicinal properties of plants, extracts of animals and marine life had created through careful observation, trial and error, a vast heritage of knowledge and expertise in different ethnic cultures and civilizations. Most of such indigenous knowledge was handled down, through the ages, by oral tradition while the practices in general have had to meet the need of the local communities.

Medicinal products are not basically recognized as an important source of economic in Tanzania, neither has developed mechanism in place to control and organize the market, trade and integrate supply chain of the industry. However, the there are a number of stakeholder with diverse interest who export medicinal product mostly from plants; example in 1999 the country exported 7,005,091 Kg worth Tanzanian Shillings 4,571mil13. The most challenges facing the traditional medicine industry in Tanzania include institutionalized supply chain development, lack of awareness, inadequate investments in research and development, manufacturer-exporter disagreements, lack of quality norms for standardization, poor marketing and trade information as well as lack of value addition strategies and facilities. If these obstacles would have been tackled the industry would have bridged sustainable economic development and affordable health care system. In our natural product group at Sokoine University of Agriculture we have been researching the medicinal Plant known as Synadenium glaucescens Pax, collected from Iringa region in Tanzania. Synadenium glaucescens is a wild euphorbiaceous medicinal plant (tree/bush) which is scarcely domesticated.

Synadenium glaucescens grows in several regions of Tanzania where is exploited for ethnoverterinary and/or ethnobotanical practices to control/treat diseases. It is among plants highly exploited by the communities around Usambara Mountains which pose threats for its disappearance in the wild. Domestication of the plant has been exercised as an adaptation strategy. The aim of this paper is to give a highlight on the on-going studies at Sokoine University of Agriculture to enhance its sustainable utilization by stepwise scientific/bioassay guided studies towards its commercialization.

METHODOLOGY

Collection of indigenous knowledge and plant materials

In order to study the plant, obtaining ethnobotany information was basic and fundamental. The ethnobotanical survey was conducted in the southern highland zone of Tanzania and aimed at obtaining key information on awareness and use of the plant for different purposes. Apart from literature search, questionnaires were administered to different age groups in Njombe district, Njombe region and Mufindi district, Iringa region while the focused group discussion was conducted for key target group which were traditional healers and local elderly (above 50 years). All Plant materials were collected with the aid of the local people and botanist, who identified the plant and store the Voucher specimen at herbarium of the University of Dar es Salaam. Materials for bioassay studies were collected only from a Specific village chosen for study. The flesh plant material were collected in areas found at altitudes between 1650m and 1950m above sea level, located between S08º 34^0 to 08º 49^0 S and 034 º 550 to 035 º 10^0 E.

Extraction Methods

Flesh plants collected were air dried and pulverize to size of 1mm for solvent extraction or cut to pieces for local boiling methods. The samples were subjected to cold and hot extraction methods to obtain crude extracts. The hot extraction method included sequential Soxhlet extraction with organic solvents and local boiling with water. Cold extraction employed socking sequentially with organic solvents. All further work were done by fractionation of the crude extracts to obtain fractions which were further used for isolation of pure compounds using chromatographic techniques.

Cytotoxic studies

Brine Shrimp Cytotoxicity study was conducted using the crude extracts to guide the possible medicinal properties of plant the extracts.

Bioassay studies

Bioassay studies were guided by the results from the ethnobotanical studies and cytotoxic studies. Antiviral studies were done using an In ovo assay following the

Three viruses of veterinary importance 13C/SUA Newcastle Disease Virus (NDV) strain, Infectious bursal disease Virus (IBDV) and Fowl pox Virus (FPV), all local isolates from SUA that affect chickens in particular the local chickens were used as test organisms. The local isolates were supplied by the Bacteriology and Mycology Laboratory, Department of Veterinary Microbiology and Parasitology, SUA. Antibacterial and antifungal studies were done using the agar well diffusion method according to Perez, et al. (1990) and Standard tube dilution method for tuberculosis strains sensitivity testing (TB) . The methods by Eloff (1998b) and Obi et al., 2007 were adopted at different times to determine Minimum inhibitory concentrations (MIC). Bacteria species of medical importance were used, which were Staphylococcus aureus (ATCC 29212 and ATCC 25923), Enterococcus faecalis (ATCC 29212), Pseudomonas aeruginosa (ATCC 27853 and SUALI) and Escherichia coli (ATCC 25922 strains obtained from Pretoria University, MUHAS and SUALI). Bacillus subtilis, Streptococcus pyogenes and Salmonella typhimurium bacterial isolates were also tested. Six Mycobacterium tubercullosis strains 151, AP7, AP43,AP49, AP50 and AP63 supplied by SUA TB project were also tested for their sensitivity against some fresh and dried plant extracts. Fungal test organisms used in were Aspegillus Niger (AZN 8240), Candida albicans (ATCC 90028) and Cryptococcus neoformans (LI) supplied by the Bacteriology and Mycology Laboratory, Department of Veterinary Microbiology and Parasitology, SUA.

RESULTS AND DISCUSSION

Approaches to commercialization of SG products:

Approaches to product/drug discovery using higher plants to reach the market can vary. Two approaches were taken towards commercialization of SG products. One being the scientific, systematic approach (SSA) adopted drug discovery approaches while the other named traditional approach (TA)(see fig 1) which is now common to many plant products in the local markets. Scientific systematic approach is always a long process which takes up to 10 years and always very expensive because it involves pure active ingredient discoveries. The process can be discouraging and sometime can be terminated at stages during clinical studies either due to inactiveness or toxicity of the active ingredient/product. Traditional preparation/products can be active crude extracts used to formulate a product or used as it is at standardized stage or locally made. The advantage of TA is that the entry to the local market can be cheaper and shorter compared to the SSA, thus allows testing of other options if any failure occurs. With this regard the results presented in this paper follow the two approaches basing on the ethnobotanical information obtained from the survey.

Findings from the ethnobotanical survey

Awareness on the ethnobotanical value of SG

It was found that 94% of the interviewees were aware of the medicinal and other value of the plant among which 78% have personally used it for medical purposes and that leaves and roots are the most parts used during medication. The community has accumulated knowledge with experience on how to handle the plant due it toxicity thus 77% acknowledge that the plant was toxic but argued that, it does not stop them from exploiting it for medicinal and other used. They mentioned toxic effects such eye blindness and corrosive to skin, if sap get in contact with the organs, stomach aches, bloody diarrhea, pains even death due to overdose. Seventeen uses were established during this survey these included:

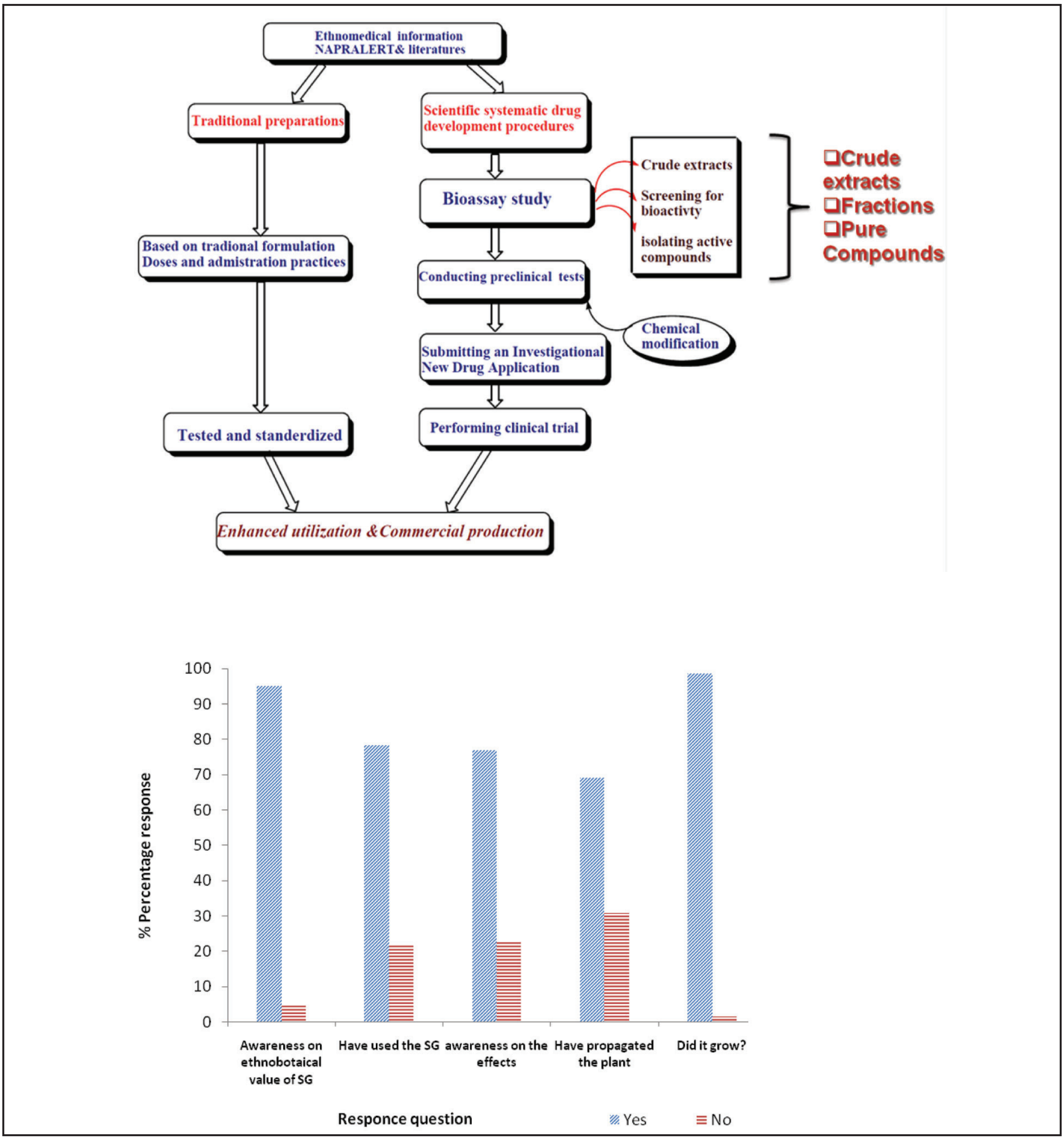

Figure 2: Showing %responses of the respondent to question during the ethnobotanical survey

Relief for stomach, teaat and backbone aches, wound healing, induction of abortion, treatment/control of New castle diseases, control East Cost Fever in cattle, treatment of turbaclosis, treatment of worms in animals and human, treatment of ear problems, treatment of cellulitis, tumor treatment/control, relief mensturation pains, treatment STDs, Glue, grain conservation, Illegal fishing, protection of farms and for repaling insects. Of the respondents 69% have attempted to grow the plant of which 99% successfully domesticated the plant as an adaptation to its disappearance in the forests. The respondents also reported that the plant is easy to grow and it does not need much water for germination during propagation even for growing.

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The respondents have demonstrated a high knowledge on observing the trend towards disappearance of the plant example: though 96% agree that the plant is available 80% agreed that the abundance of the plant is going down compared to few years back. This can be attributed by many factors including deforestation for farming and drought. Further studies of the plant especially on tissue culture and propagation will create more opportunity for the exploitation of the plant at commercial level in a sustainable manner while enhancing carbon sequestration as mitigation strategy of climate change. Domestication demonstrates a current adaptation to its disappearance in the wild. As we are moving ahead chemistry studies, synthetic chemistry approaches will reduce its harvest in the wild

Cytotoxicity Screening: Brine Shrimp Lethality test

Extracts of SG could be both bioactive and anticancer as they all demonstrated the LC50 below 30 µg/ml which validates the experience as reported by the local people for the plant being highly corrosive and toxic to human being and fish. However, this also indicated that the extracts from S. glaucescens could be both bioactive and anticancer. The LC50 values for Brine Shrimp Lethality test have been reported for many toxins and plant extracts (Parra et al., 2001; Oyewale et al., 2004). According to Meyer et al. (1982) and Parra et al. (2001), LC50 value lower than 1000 µg/ml is considered bioactive in toxicity evaluation of plant extracts by BSL bioassay while other scholar consider the toxicity below 100 µg/ml. Others consider LC50 of <20 µg/ml as very toxic and suggestive of anti-cancer activity.

Bioactivity findings of the SG extracts through SSA

Antibacterial studies

The antibacterial results indicated that, extract are active against most of the bacterial isolate and therefore the plant has the indicated potential for treatment of bacterial diseases. The gram positive bacteria were generally more susceptible as compared to Gram negative bacterial isolates. Gram negative bacterial strain are resistance against most antibiotics is associated with the presence of double membrane layer and trans-membrane efflux which together could lead to combined exclusion effect to antimicrobial compounds. Generally the polar extract of the plant root SSE1 were found to be the most effective with MIC as low as of 0.08mg/ml against S. aureus species as compared to less polar extracts and thus were carried for further studies. Fractionation of SSE1resulted to four fraction of which fraction SV4 was the most active with MIC value on 0.09mg/ml against E. Coli. Pure compound isolated from this fraction showed the lowest MIC value of 0.003mg/ml against P. aeruginosa.

Antifungal activities

Extract SSE1 was moderately active against C. Albicans and Aspegillus niger with zone of inhibition of 12mm and 15mm respectively. Its fraction, SV4 demonstrated activity on the same range. The ethnobotanical studies indicated that the plant is used in treatment of some topical fungal infections. Further studies to assess its usefulness in the control of HIV opportunistic infections that include C. albicans in line with what has been reported by traditional healers where this plant was collected could be more informative.

Antiviral screening

Extract SSE1 showed the highest activity in the antiviral assay by reducing the viral load and prevent death of the embryos. The viral load in eggs treated with E1S reduced for up to mean of 99.2% with the weight increase of 87% compared to the positive control i.e. embryo inoculated with virus alone.

No death of embryo observed and no Pox lesions were observed in the embryos treated with both FPV virus and E1S. No death or deformation of embryos observed in chicken embryonated eggs infected with IBDV and E1S. this was an indication that . It is possible that some of the viruses were killed with extract during the mixing with extract while in the embryo there was a mechanism that developed and was able to prevent more multiplication of virus at least during the 4 days of incubation of the eggs.

Bioactivity findings of the SG extracts through TA

In vivo studies were conducted on wound healing promotion of swiss albino mice infected with S. aureus and P. Aeruginosa. All mice infected with test strains survived, however the wound healing characteristics were different. Those mice treated with DES experienced wound healing as soon as the fourth day of treatment. Up to 5th day, all mice were observed with healed wound. Important observation includes death at higher doses of the extracts and death at higher doses of infection organisms. Preliminary studies on the effectiveness of the water extracts of the dry leaves were used for treatment of scaly legs disease in local chicken the mites were cleared and the chicken went back to normal. Further systematic research work is planned on this experiment Linked indigenous knowledge to Science.

The backbone of this work is built on the indigenous knowledge as provided by the communities in Iringa. Both local and scientific extraction methods were used in the study. All the laboratory work was guided by the information collected from the ethnobotanical survey. Selection of test strained for sensitivity tests, in vivo and in ovo trials basically took into consideration the causative agents of medical conditions mentioned by the respondents during the survey. This was done in order to bridge up the scientific and ethnobotanical knowledge of the community in Iringa region. Indigenous people have knowledge and own their knowledge. The bridge between science and indigenous knowledge such as ethnobotany, are of vital importance in the current world and it gains more acceptance. Though Scientists for long time now have assumed that indigenous communities must change to meet modern standards, it is a feeling now and some scholars have pushed that scientists and society must begin to respect the consecrated knowledge that indigenous people have known for generations. The knowledge has been learnt from direct observation of the land over thousands of years and gathered lots of practical experiences on continued use of the land and vegetation in particular .

Intellectual Property Right (IPR)

Intellectual Property Rights (IPR) today commands much attention globally than ever before. In stepwise research aiming at commercialization of SG products at an industrial scale, and in order to facilitate technology development and transfer within /from outside the nation while sharing the economic benefits arising, the extracts of

SG with interesting activities were patented. Two national patents with numbers TZ/P/10/00274 and TZ/P/10/00280 have been granted to SUA based on findings from on-going research on SG.

The chemistry part of the plant:

The chemical structures of the pure compounds of the plant is still not known, the current continuing work to reveal the pure compounds isolated is ongoing. However preliminary phytochemical screening suggests some polyphenolic components in the polar component of which, it was more bioactive compared to other extracts.

CONCLUSION AND RECOMMENDATIONS

From the ethnobotanical survey it is revealed that indigenous knowledge is rich and can be well validated using scientific methods. The plant extracts possess compounds with antimicrobial properties that can be used as antibacterial, antiviral and antifungal agents and thus it validates the exploitation by the community. This is very useful information in attempts towards product development and it demonstrate a high potential of commercializing of the products from the extracts of the SG. Further studies of the plant especially on tissue culture and propagation will create more opportunity for the exploitation of the plant at commercial level in a sustainable manner while enhancing carbon sequestration as mitigation strategy of climate change. Domestication demonstrates a current adaptation to its disappearance in the wild. As we are moving ahead chemistry studies, synthetic chemistry approaches will reduce its harvest in the wild.

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PHYTOPLANKTON COMPOSITION AND ABUNDANCE IN RELATION TO PHYSICO-CHEMICAL PARAMETERS AND NUTRIENT CONCENTRATIONS DURING THE DRY SEASON IN THE WAMI ESTUARY, TANZANIA

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ABSTRACT

A study on phytoplankton community structure and its relation to other water quality variables was conducted in the Wami river estuary, Tanzania, in October 2010. The aim was to understand the basic water quality condition {water temperature, salinity, dissolved oxygen, pH, Total Suspended Solids (TSS), Soluble Reactive Phosphate (SRP) and NO3} when fresh water flow to the estuary is at its minimum level as well as to lay a foundation for future scientific studies. Data collection was done once a week over a period of four consecutive weeks during high and low tides. SPSS 16.0 and Golden Grapher 6.0 Software were used for analysis and presentation of the data. Diatoms, cyanobacteria and dinoflagellates dominated the phytoplankton community. Phytoplankton abundance ranged from 0.05 x 105 to 43 x 105 cells l-1 and 0.1 x 105 to 38.1 x 105 cells l-1 during high and low tides, respectively. The estuary was well mixed and dominated by marine-water with low water depths which averaged between 2.5 m and 1.5 m during high and low tides, respectively. Water temperature ranged between 29.5^{0}C - 30.8^{0}C, salinity ranged between 4.1 and 36 and pH ranged between 7.6 and 8.1. Dissolved oxygen ranged between 7.9 and 8.9 mgl-1 and TSS ranged between 61.59 and 76.34 mgl-1. SRP ranged between 0.209 and 0.358 mgl-1 while NO3- ranged between 0.017 and 0.128 mgl-1. Results show that phytoplankton composition and abundance were highly influenced by tidal flushing than any other factors. Furthermore, phytoplankton community structure indicated the low species composition but high abundance.

Keywords: *Wami estuary, nutrients, phytoplankton, salinity, temperature dissolved oxygen, freshwater flow*

INTRODUCTION

In aquatic ecosystems, phytoplankton are primary producer whose dynamics and general community structure are highly influenced by complex interactions of several abiotic and biotic factors (Spatharis et al., 2007; Arimoro et al., 2008; Glé et al., 2008; Zhaohui et al., 2009; Arndt, 2011). The abiotic factors include changes in nutrient concentrations, light availability, variability of physico-chemical parameters, and hydrodynamic and mixing regimes particularly in estuaries (Filardo and Dustan, 1985; Ferreira et al., 2005; Abid et al., 2008; Muylaert et al., 2009; Arndt, 2011). In most cases, increasing nutrient loading to aquatic ecosystems tends to increase phytoplankton productivity leading to excessive growth of harmful algae blooms and eutrophication. On the contrary, certain groups of phytoplankton such as dinoflagellates tend to produce high amount of toxins under nutrient limitations (Maestrini et al., 2000; Guisande et al., 2002). This helps as a compensatory strategy of minimizing dinoflagellates competitive disadvantage under nutrient limitations (Frangópulos et al., 2004).

Light availability drives photosynthetic activities within the water column hence increasing phytoplankton productivity whereas light limitation by turbidity and suspended solids reduce productivity, particularly in non-motile species (Peterson and Festa 1984; Cloern, 1987). Biotic factors include grazing pressure and competition within different trophic levels (Alpine and Cloern, 2001; Hillebrand and Kahlert, 2002; Glé et al., 2008). Additionally, riparian vegetation such as mangroves may also affect phytoplankton diversity. A study conducted by Tundis et al., (1973) indicates that certain Rhizophora species tend to reduce phytoplankton diversity by releasing tannins from their roots and decomposing wood and leaves.

The major mineral elements that influence phytoplankton productivity, composition, and abundance are nitrogen, phosphorus and silicon. Nitrogen has been considered the limiting nutrient in marine and estuarine ecosystems while phosphorus is the limiting nutrient in freshwater ecosystems (Bernhard and Pelle, 1997). Silicon in the form of orthosilicic acid or silicate is considered the main factor influencing diatom growth (Paasche, 1973; Martin-Jezequel et al., 2000; Gilpin et al., 2004).

However, in estuarine ecosystems it becomes very difficult to clearly state which nutrients exactly are the limiting factors due to complex interactions between freshwater and marine water, which vary both spatially and seasonally. For example, a shift from phosphorus to nitrogen limitations may occur during periods of reduced river discharge (Snow et al., 2000; Cloern, 2001). In addition, variability of phytoplankton composition during tidal cycles can also be influenced by horizontal mixing of water due to tidal currents, vertical mixing of water column due to wind stress, and advection of water due to the gradient of water density (Cloern, 1996; Pinckney et al., 1999). Nonetheless, less is known about other environmental drivers and how they induce a temporary change in phytoplankton composition and abundance at smaller time scales, mainly in toxic species.

Most of phytoplankton studies in Tanzania have been conducted in oceanic waters, large rivers, lakes and other freshwater environments (e.g Lugomela, 1996; Lugomela et al., 2002). There are no phytoplankton studies that have been conducted in estuarine environments in the country. The present study was carried out in Wami estuary in Northern coast of Tanzania during the dry season. It offers an opportunity to understand the water quality condition based on phytoplankton composition and abundance in relation to some environmental parameters. The study findings provide an ecological baseline for future studies of phytoplankton community structure and the general water quality of the estuary.

MATERIALS AND METHODS

Study area

The Wami River estuary is located in the northern coast of Tanzania within the Wami-Ruvu River Basin and Saadani National Park. It is a small and shallow deltaic estuary with tidal limits extending up to 7km upstream (Figure 1). The freshwater discharge to the estuary during the dry season at the rate of 3m3sec-1.

The estuary is dominated by mangrove forests within the first five kilometers from the river mouth, followed by acacia dominated stands and open grassland vegetation interspaced with some mangroves, and palm vegetation (Nypa fruticans) within the areas of tidal limits (Anderson et al., 2007). The dominant mangrove species are Avicennia marina, Xylocarpus granatum, Ceriops tagal, Rhizophora mucronata and Heritiera litoralis. The estuary is a very important ecosystem for the Saadan National Park and the adjacent communities. It provides water for wildlife in the park and habitat for a large number of aquatic mammals, crustaceans, birds, fish and reptiles. Main human activities in the estuary include fishing, salt making and tourism. There is a small fishing camp at the river mouth with a population of approximately one hundred people.

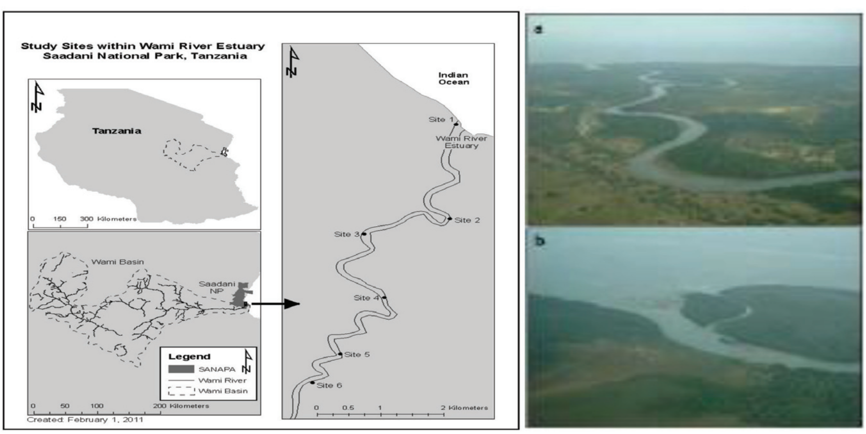


Figure 1(left): Location of the study area and sampling sites, (right): Wami estuary entering the Indian Ocean and (b) deltaic feature of the estuary

Data collection

This was done at six sites in the Wami estuary in October 2010 during both high and low tides once a week for a period of four consecutive weeks. Samples of phytoplankton for identification and quantification were prepared by concentrating 20 liters of estuarine water through a 10 µm mesh size plankton net into 100 ml. The samples were preserved in formalin at 4% concentration and stored in small dark brown bottles. Identification of phytoplankton in the laboratory was done by using a light microscope (OLYMPUS HBZ) under 100X and 400X magnifications while counting was done in 1ml capacity Sedwick-Rafter cell (Woelkerling et al., 1976). For nutrient analysis and total suspended solids (TSS), 400ml of water were filtered through a BOECO glass-microfibre discs grade MGC with 0.45 µm pore size into acid washed bottles, transported to the laboratory in iced cool box and stored in a deep freezer at a temperature of -20oC while awaiting analysis. Cadmium reduction method by Parsons et al., (1984) was used for analysis of Nitrate (NO3- -N) while the ammonium molybdate method by Murphy and Riley, (1962) was used for soluble reactive phosphate (SRP) (PO4-3-P) analysis. The filter papers containing residue were used for analysis of TSS following the protocol described by APHA (2005). In situ measurements of water temperature, pH and dissolved oxygen were done using a handheld water quality checker HORIBA model U-10 while salinity was measured using a hand refractometer ATAGO model S-10. SPSS 16.0 and Golden Grapher 6.0 Software were used for analysis and graphical presentation of data.

Study limitations

- Low water flows during low tide hindered data collection in upstream sites (4, 5 & 6).
- Lack of hydrological and meteorological data to supplement study findings

RESULTS

Physicochemical parameters

High values of physico-chemical parameters (water temperature, salinity, dissolved oxygen, pH and TSS) were recorded during high tide, except for water temperature and dissolved oxygen at sites 2 and 3. For nutrient concentrations, SRP showed higher values than NO3- concentrations throughout the sampling sites. The lowest values for nutrients were recorded at the river mouth and highest values at the mid and upper estuary. Values for physico-chemical parameters and nutrients at high and low tides are summarized in Table 1while their variations across sampling sites are shown in Figure 2.

Table 1: Physico-chemical parameters and nutrient concentrations at high and low tide.

S/n	Parameter	High tide	Low tide
1.	Water temperature	30.1 - 30.8°C	29.5 – 30.7°C
2.	Salinity	4.6 – 36	4.1 – 22.6
3.	Dissolved oxygen	7.9 – 8.9 mgl^{-1}	8.1 -8.3 mgl^{-1}
4.	pH	7.7 – 8.1	7.6 – 7.8
5.	TSS	61.59 – 76.34 mgl^{-1}	65.50 – 67.66 mgl^{-1}
6.	SRP	0.229 – 0.358 mgl^{-1}	0.209 – 0.279 mgl^{-1}
7.	NO3-	0.017 – 0.128 mgl^{-1}	0.042 – 0.10 mgl^{-1}

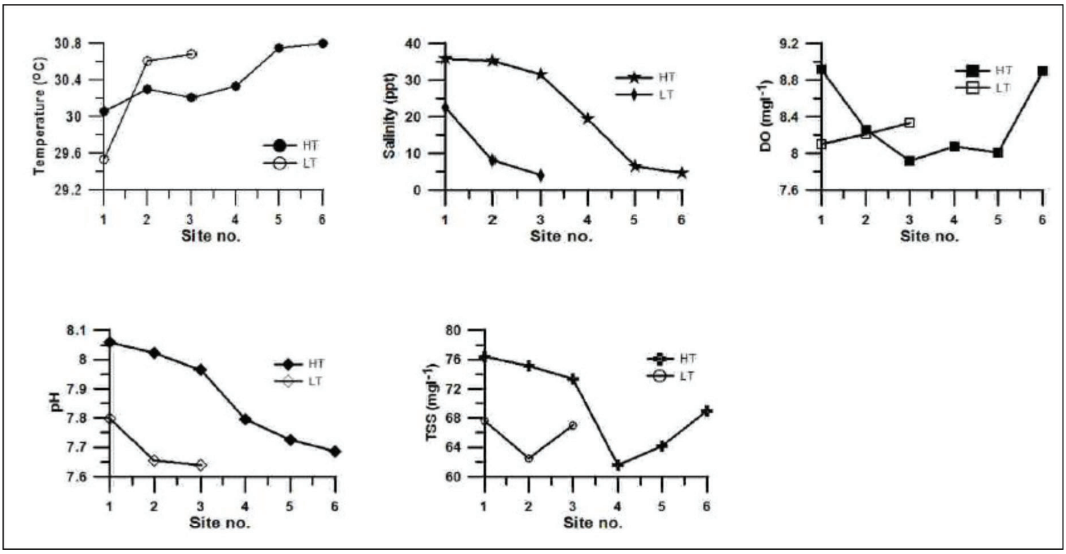


Figure 2: variations of physico-chemical parameters across sampling sites (HT= High tide, LT = Low tide).

Phytoplankton composition

Microscopic enumeration indicated phytoplankton species of Bacillariophyta, Cyanobacteria and Dinoflagellata to be present and dominant throughout the estuary. A total of thirty one (31) genera of Bacillariophytes (mainly diatoms), thirteen (13) genera of Cyanobacteria and eight (8) genera of Dinoflagellata were identified. Photographs of some of the identified species are shown in Plate 2. Species composition varied between tidal cycles with more species identified at high tide. The most dominant species of diatoms at high tide were Rhizosolenia sp., Pleurosigma sp., Paralia sp., Coscinodiscus sp. and Odontella sp. The same species dominated at low tide with the addition of two species; Belleroches sp. and Chaetoceros sp. Despite the changes in composition for both cyanobacteria and dinoflagellates, the dominant species remained the same. These were Anabaena sp. and Oscillatoria sp. for cyanobacteria and Protoperidinium sp. for dinoflagellata. A list of all phytoplankton species identified during high and low tides is presented in Tables 2 and 3.

Table 2: Phytoplankton species recorded during high tide at Wami River estuary.

Species identified	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Bacillariophyta						
Actinoptychus sp.	X	X	X		X	X
Amphiphrora sp.					X	
Asteromphalus sp.	X	X		X		
Bellerochea sp.		X				
Biddulphia sp.	X	X				
Chaetoceros sp.				X	X	
Coscinodiscus sp.	X	X	X	X	X	X
Diploneis sp.				X		X
Donkinia sp.				X		
Guinardia sp.		X		X		X
Gyrosigma sp.						X
Hantzschia sp.			X			
Isthmia sp.	X		X		X	
Leptocylindrus sp.					X	X
Lithodesmium sp.					X	
Navicula sp.				X	X	X
Odontella sp.	X	X	X	X	X	X
Paralia sp.	X	X	X	X	X	X
Pleurosigma sp.	X	X	X	X	X	X
Rhabdonema sp.			X		X	
Rhizosolenia sp.	X	X	X	X	X	X
Skeletonema sp.				X		
Thalassiothrix sp.			X	X		X
Thallassiosira sp.		X				
Cyanobacteria						
Anabaena sp.	X	X	X	X		
Aphanizomenon sp.						X
Microcoleus sp.					X	
Nostoc sp.					X	
Oscillatoria sp.	X	X	X	X	X	
Planktolyngbya sp.					X	
Planktothricoides sp.		X				
Schizothrix sp.					X	
Trichodesmium sp.		X	X			
Dinoflagellata						
Amphidinium sp.						X
Prorocentrum sp.	X		X	X		
Protoperidinium sp.	X	X	X		X	
Pyrophacus sp.		X	X			

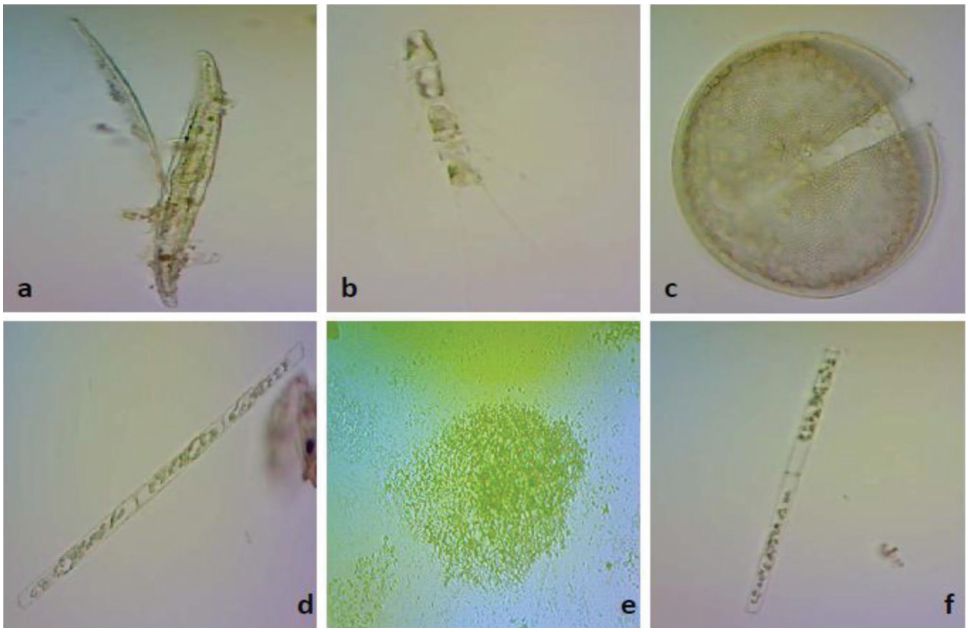
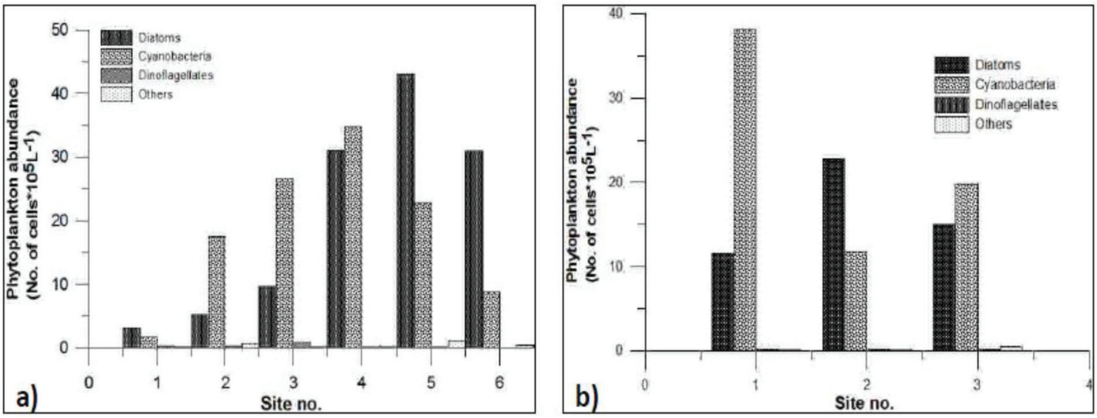


Plate 2: Some of the phytoplankton species identified from Wami estuary:
(a) Pleurosigma sp. (b) Chaetoceros sp. (c) Coscinodiscus sp. (d) Guinardia sp.
(e) Microcystis sp. and (f) Leptocylindrus sp.

Phytoplankton abundance

Phytoplankton abundance across the sampling sites ranged from 0.05 x 105 to 43 x 105 cells l-1 and 0.1 x 105 to 38.1 x 105 cells l-1 during high and low tides, respectively (Figure 3). Cyanobacteria abundance increased from site 1 to site 4 and decreased from site 4 through site 6 at high tide. They were less abundant at site 1 (1.7 x 105 cells l-1) and more abundant at site 4 (34.7 x 105 cells l-1). During low tide, cyanobacteria were more abundant (38.1 x 105 cells l-1) at site 1 and less abundant (19.9 x 105 cells l-1) at site 3. Diatom abundance showed similar trends to cyanobacteria during high tide, but the highest abundance (43 x 105 cells l-1) was observed at site 5 and the lowest abundance (3.2 x 105 cells l-1) at site 1. During low tide diatoms were more abundant (22.7 x 105 cells l-1) at site 2 and less abundant (11.6 x 105 cells l-1) at site 1. Although the abundance of dinoflagellates was very low compared to other taxa, the highest abundance (0.8 x 105 cells l-1) was observed at site 3. Dinoflagellates abundance was very low (0.2 x 105 cells l-) compared to the other groups, and it was the same for the three sites at low tide. However, comparisons between different groups of phytoplankton during both high and low tides show different trends within the first three sites. For instance, during high tide, abundance of all phytoplankton groups increased from site 1 towards site 3 while at low tide cyanobacteria abundance decreased from site 1 to site 2 and increased at site 3. Again, diatoms abundance



Generally, phytoplankton abundance did not show significant correlations with physico-chemical parameters (physico-chemical and nutrients) during both high and low tides ($p > 0.05$ for all). However, during high tide, phytoplankton showed an increasing trend with increasing SRP from the river mouth towards the upper estuary. For NO3-, a similar trend was observed from site 3 to site 6 only. At low tide, an increasing trend from site 1 to site 2 and decreasing trend from site 2 to site 3 was observed for diatoms and vice versa for cyanobacteria for both SRP and NO3-. Additionally, high abundances of both diatoms and cyanobacteria were observed at site 4 when the concentration of TSS was very low. At high tide, phytoplankton abundance increased from site 1 towards site 4 as the concentration of TSS decreased and decreased from site 4 to site 6 as the concentration of TSS increased. However, during low tide cyanobacteria abundance decreased from site 1 to site 2 as the TSS concentration decreases and increased from site 2 to site 3 as the TSS concentration increased. For diatoms, the abundance increased with decreasing TSS concentration from site 1 to site 2 and decreased from site 2 to site 3 with increasing TSS concentration. Phytoplankton abundance did not show any variations with salinity changes along the estuary, though at high tide increasing phytoplankton abundance from site 1 to site 4 coincided with decreasing salinity (Figure2 and 3 above).

DISCUSSION

Estuaries normally support fewer species of phytoplankton than any other transitional environments (e.g. tidal flats, swamps and lagoons) due to high variability of hydrological patterns (Costa et al., 2009). Results from the study show that phytoplankton composition and abundance were more influenced by tidal flushing than any other factors. This is because in October the Wami River freshwater flow becomes very low to the extent that the estuary became mainly seawater dominated. Seawater dominance in the Wami estuary is also supported by the findings of the study that most of the identified species were represented by marine and few estuarine species.

Additionally, during high tide lower phytoplankton abundances and composition were observed in the lower estuary when the tidal currents from the sea to the estuary were strong, while high abundances and composition were observed in the upper estuary when the effect of tidal currents is reduced. This suggests that more phytoplankton were pushed further upstream as a result of strong tidal current from the sea to the river. At low tide when the effect of tidal currents was reduced, high abundances and composition of phytoplankton were observed in the lower estuary. The very low composition and abundance of dinoflagellates could be due to their inability to tolerate high water turbulences (Karleskint et al., 2009). Furthermore, under highly fluctuating environments and shallow estuaries where their vertical mobility is restricted, dinoflagellates tend to form dormant cysts and sink to the bottom of the water (Dale, 1983). Nonetheless, other factors such as TSS concentrations, grazing by zooplankton and benthic filter feeders, salinity, and nutrient concentrations could have influenced the abundance and composition of phytoplankton in the estuary. High abundances were observed in regions of low TSS concentrations and vice versa. Grazers and benthic filter feeders could have been brought from the sea to the estuary by tidal currents. A study conducted by Phlips et al., (2002) indicates that the grazing rate by planktonic grazers can be high enough to overcome phytoplankton growth rates, hence lowering abundance. Also, rapid changes in salinity may cause stress to phytoplankton, though certain species of cyanobacteria have a tendency to tolerate high osmotic stress (Apte, 2001).

Nutrient concentrations did not show much effect on the abundance and composition of phytoplankton. Nevertheless, diatoms showed similar increasing and decreasing pattern to SRP and NO3- concentrations throughout the tidal cycles. This suggests that N could be the limiting element for diatom growth in the estuary. In many tropical estuaries, P is the limiting factor to phytoplankton growth although nutrient limitation is species-specific (Cloern, 2001). These limitations may also change depending on the nutrient spatial variability as a result of changing freshwater flows (Murrel et al., 2002). Certain species of phytoplankton, mostly dinoflagellates and cyanobacteria tend to either produce toxic substances or form algal blooms which sometimes become harmful. Toxin production by dinoflagellates has been explained as one of their compensatory strategies to minimize the competitive advance of other phytoplankton groups under nutrient limitation conditions (Frangópulos et al., 2004). Some dinoflagellates are known to cause paralytic shellfish poisoning (PSP), diarrhetic shellfish poisoning (DSP) and harmful algal blooms e.g. red tides (Alkawri and Ramaiah, 2010). Despite their high abundance in aquatic environments, very few species of diatoms produce toxins. However, some species have been reported to form algal blooms in nutrient rich environments.

Results of phytoplankton composition from the Wami estuary indicate the presence of potentially harmful cyanobacteria and dinoflagellates species. Some of these species have been reported to occur in nearby marine waters of Zanzibar, Tanzania (Kyewalyanga and Lugomela, 2001) and other parts of the world (Vila and Masó, 2005).

These species which were also recorded in Zanzibar waters are composed of cyanobacteria; Anabaena sp., Nostoc sp., Oscillatoria sp., Schizothrix sp. and Trichodesmium sp. and Dinoflagellates; Prorocentrum sp., Amphidinium sp., Dinophysis sp., and Gonyaulax sp. Other phytoplankton species recorded during the study which are known to be potentially bloom forming include Leptocylindrus sp., Skeletonema sp. and Prorocentrum sp. (Ibid). Fortunately, none of the diatoms species recorded during the sampling period are known to be potentially toxin producing species.

Cases of PSP, DSP and algal blooms have not been reported in lower Wami river and estuary so far, however, presence of these phytoplankton species even in small numbers could be an indication of the potentiality of the problem to occur. Alkawri and Ramaiah (2010) cautioned that presence of more than 1000 cells l-1of known potentially toxin producing phytoplankton should be taken as an indication of possibility of the problem to occur in a given area.

CONCLUSION

Phytoplankton community structure indicates the low species composition but high abundance. The major phytoplankton groups identified in the estuary include diatoms, cyanobacteria and dinoflagellates. Potentially harmful phytoplankton species in terms of toxin production and algal blooms formation were found to be present in the estuary. Although there are no reported cases of algal blooms and shellfish poisoning, presence of these species in the area indicate the potentiality of these problems to occur. Continuous monitoring of hydrologic conditions of the estuary is very important particularly freshwater discharge, water quality and estuarine ecosystem condition

RECOMMENDATIONS

- A continuous monitoring of water quality parameters (physical, chemical and biological) in order to have a better understanding of their spatial and temporal variations is recommended.
- Nutrient budget and sediment analysis studies to have a clear understanding of sources and dynamics of nutrients are crucial.
- Water quantity (river discharge, flow rates) -This is done in some parts of the river, however data recording and storage is not done properly. Therefore, there is a need to establish a good and efficient method of data storage.
- Effective monitoring and data storage for meteorological parameters such as rainfall, wind, temperature and evaporation are recommended.

- Toxicity tests for shellfish and molluscs to determine if there is a potential for PSP and DSP to occur in the area is important.

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EXAMINING THE INFLUENCE OF CLIMATE CHANGE MITIGATION PROJECT ON ADAPTIVE CAPACITY: A STUDY OF THE IMPACT OF BIOFUEL PROJECT ON RURAL POOR IN BAGAMOYO DISTRICT, TANZANIA

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ABSTRACT

Climate change is a global problem that has received much attention in recent decades. There is a common understanding that climate change impacts can have catastrophic effects, especially on economically and socially marginalised groups. The discourse on climate change usually emphasises the importance of both mitigation and adaptation. Anthropogenic impacts of climate change are increasingly certain and this calls for a dual response involving mitigation of the causes and adaptations to impacts. However, the two responses are linked, to a degree and relatively little attention has been given to the potential impacts of some of the mitigation measures proposed so far, such as the use of biofuels, to the capacity to adapt. This is particularly important in marginalised rural populations in developing countries, where projects focusing on biofuel production are increasingly being implemented while disregarding their impacts on environmental resources such as wildlife, forests and water. This paper attempts to better understand the adaptive capacity of local communities to biofuel projects in a developing world setting with reference to an empirical case study carried out in Bagamoyo district, Tanzania. In particular, adaptive capacity is examined in its social ecological context. Economic resources, institutions and information technology (IT) are important determinants of adaptive capacity and are used as measurement categories in this paper. Using data generated from an application of participatory rural appraisal methods, household interviews and the construction of historical profiles, the study confirms that economic resources, IT, and institutional arrangement influence the adaptive capacity of marginalised rural poor in the study area to external perturbations, including the introduction of biofuel projects and climate change at large. The study informs both the climate change debate and decision makers on the potential impacts of biofuels on the adaptive capacity of local communities and wildlife conservation at large.

Key words: *climate change, adaptive capacity; biofuels; local communities; Bagamoyo, Tanzania.*

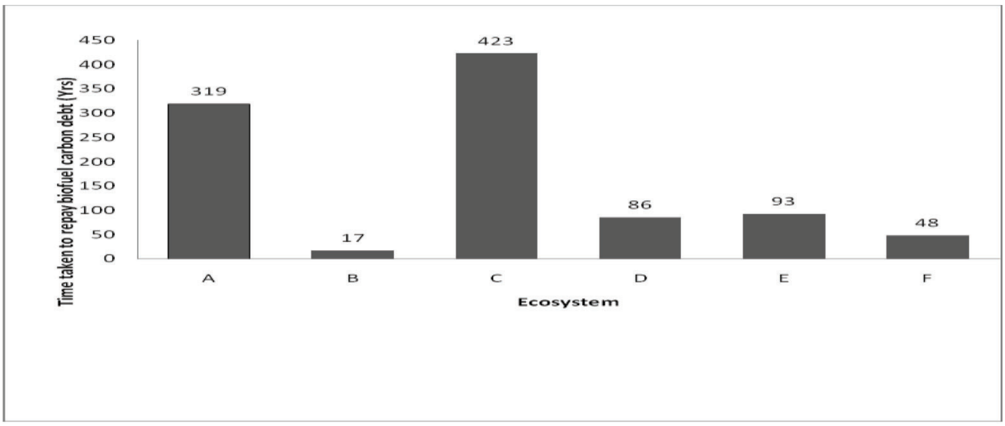
INTRODUCTION

It is widely expected that global warming will have catastrophic effects, especially on economically and socially marginalised groups (Adger, 2001, Klein et al, 2003). Global discussions on how to potentially avoid and reduce climate change effects principally focus on two measures: 1. Climate change mitigation 2. Adaptation to climate change effects. Mitigation is the action of decreasing the intensity of radiative forcing in-order to reduce the possible effects of global warming (IPCC, 2007). This is mainly achieved by reducing the concentrations of greenhouse gases, either by reducing their sources or by increasing their sinks (Molina et al, 2009). Adaptation, on the other hand, involves acting to better tolerate and respond to the effects of global warming. While mitigation is more strongly promoted in carbon emitting industrialised countries, there is a common consensus that adaptation to the effects of global warming are most urgently needed in developing countries, which are those countries expected to be affected most dramatically by global warming (Moench, 2005).

One of the most prominent strategies for mitigation is the partial replacement of fossil fuels by biofuels, although studies show that in some scenarios of biofuel production it can take several years to clear the carbon debt associated with direct land use change for the process (Figure 1) (Fargione et al., 2008). Proponents of biofuels (UN, 2007; Cotula et al, 2008) argues that the production of biofuels, especially in developing countries, will lead to poverty alleviation through employment, taxes, technology transfer and general rural development (GTZ, 2006; Khoti, 2008; Gordon-McLean et al, 2008). In view of the expected benefits, internationally financed companies, strongly supported by governments from both industrialised and developing countries massively started to invest in agro-industrial plantations for the production of biofuels. Some African countries, such as Tanzania, have particularly become the focus of investors looking for large tracts of land suitable for biofuel production (Sosovele, 2008; Khoti, 2008; Gordon-McLean et al., 2008; Sulle and Nelson, 2009a) such that the rush for land acquisition in Africa has sometimes been referred to in the media as the ‘Green Gold Rush.’

In Tanzania, high energy prices, especially oil, the availability of agricultural land and the country’s needs for energy security, rural development, climate change mitigation and attraction of foreign investment are all key factors determining the suitability of the country for biofuel production (GTZ, 2006; Khoti, 2008; Gordon McLean et al., 2008). For example, current high dependence on oil imports uses around 25% of the country’s foreign reserves that could be used for other development purposes (Khoti, 2008; Sulle and Nelson, 2009b). Moreover, about 92% of the Tanzanian population depend on bio-energy (mainly firewood and charcoal) thus, contributing to forest degradation.

Yet, discussions on the measures for climate change mitigation especially on the production and use of biofuels has neglected the fact that the measures thus far proposed will have drastic effects on the marginalised poor living in rural areas. In particular, the loss of immense areas of arable land demanded for the cultivation of biofuels, as well as the application of pesticides for the management of the huge monocultures, are expected to provoke negative social and environmental problems for the rural populations living in these areas. The capacity of local communities to deal with the challenge of biofuel plantations will be decisive for the social outcomes of this mitigation strategy.



KEY
A = Indonesia/Malaysia tropical rainforest converted to palm biodiesel,
B = Indonesia/Malaysia tropical peatland forest converted to palm biodiesel
C = Brazil tropical rainforest converted to soya biodiesel
D = Brazil wood cerrado to sugarcane/ethanol
E = US central grassland to corn/ethanol
F = US abandoned cropland to corn/ethanol

This study aimed to better understand the adaptive capacity of local communities for successfully dealing with biofuel projects by exploring a case study in the Bagamoyo district of Tanzania. Findings indicate that economic resources, available information and technologies and institutional arrangements all strongly limit the adaptive capacity of communities and that strong preparatory efforts are needed to strengthen existing potentials in order to avoid potential negative social consequences of biofuel projects in rural Africa. The following section explains the conceptual framework for analysing the determinants of adaptive capacity.

The determinants of adaptive capacity

The concept of Social Ecological Systems (SES) assumes that nature and society build integrated systems with reciprocal feedbacks (Berkes and Folke, 1998, Holling, 2001). Social Ecological Systems usually show a high degree of complexity, making them highly unpredictable and uncertain (Walker et al, 2002). However, they have an inherent internal capacity to adapt to changes. This capacity is often expressed by two concepts namely resilience and vulnerability. Resilience is defined as 'the magnitude of disturbance that can be tolerated before a SES moves to a different region of state space controlled by a different set of processes'. (Carpenter et al, 2001). In this sense, resilience reflects the capacity of a system to absorb changes or disturbances (i.e. remain in a particular configuration), and involves its ability to reorganise following a disturbance or change (Carpenter et al, 2001; Walker et al, 2002). Vulnerability, in contrast, describes the propensity of the system to suffer harm from exposure to external stress or shock. In the case that a SES has lost its resilience, it becomes vulnerable to shocks and perturbations that it could have otherwise absorbed (Holling, 2001; Folke et al, 2003).

Both SES and resilience concepts directly relate to the approach of adaptive capacity, which is defined in this paper as the ability of a particular SES to cope with novel changes without losing options for the future (Folke et al, 2003). This implies the system's ability to take advantage of new opportunities or cope with new challenges while maintaining its internal controls and functions. The adaptive capacity of SES varies in both spatial and temporal dimensions and is context specific (Carpenter et al, 2001; Walker et al, 2001). In any particular community, adaptive capacity is related not only to the enabling environment, but also to the resources and processes at the community, national and international levels (Smit and Wandel, 2006). It follows the system variables that determine its new configuration that tend to change in spatial and temporal dimensions. At the local level, adaptive capacity is determined by economic wealth, technology, information and skills, infrastructure, institutional arrangement within which they occur, political influence, kinship networks and equity (Handmer et al, 2001; Smit et al, 2000; Smit and Pilifosova, 2001; Eakin and Lemos, 2005; Smit and Wandel, 2006). Based on the determinants defined by Yohe and Tol, (Yohe and Tol, 2002) and a thorough review of literature on adaptive capacity, resilience and vulnerability, this study selected three parameters to critically reflect on the adaptive capacity of three local communities in Tanzania which have been affected by a biofuel project: 1) the availability of financial resources, 2) access to information and technologies, and 3) the quality of institutional arrangements. These three parameters are applied in examining the adaptive capacity of local communities in Bagamoyo to a new biofuel project in the area.

MATERIALS AND METHODS

Bagamoyo district is one of six districts forming the Coastal Region in Tanzania. It lies between longitudes 370 and 390 East and latitudes 60 and 70 South. The district covers an area of 9,842 km2 of which 855 km2 is covered by water. The district has a humid tropical climate with seasonal average temperature ranging between 130C -

300C and rainfall of 800 - 1200mm per annum (BDC, 2006). The district has two major rivers in the north: Wami and Ruvu (Figure 3). The two rivers are the main source of water for domestic use, livestock and irrigation. Around 13km from Bagamoyo town, the Swedish company Svensk Etanolkemi of Sweden (SEKAB) hopes to invest $250 million in a project to produce biofuels from sugar cane (bioethanol). The company has already set aside about 800 hectares for seedlings, to be eventually planted in a 15,000 hectare area. In addition out-grower capacity is estimated at 5000 hectares, making an effective total of 20,000 hectares. The company expects to process and harvest 1 million tonnes of sugarcane per year, thereby producing about 90 million litres of alcohol fuel per year for both the local market and for exportation to Europe (SEKAB, 2008). The first ethanol production is expected by the year 2011 . The project will draw water from the Wami river for irrigation (Figure 3),(SEKAB, 2008). Trend analysis of flows in the Wami sub-basin, which has a population of about 1.8 million people, already indicates a predominance of declining river flows in each of the four seasons i.e. long rains, dry season, short rains and intermediate season (Pendo, 2007; Tobey, 2007).

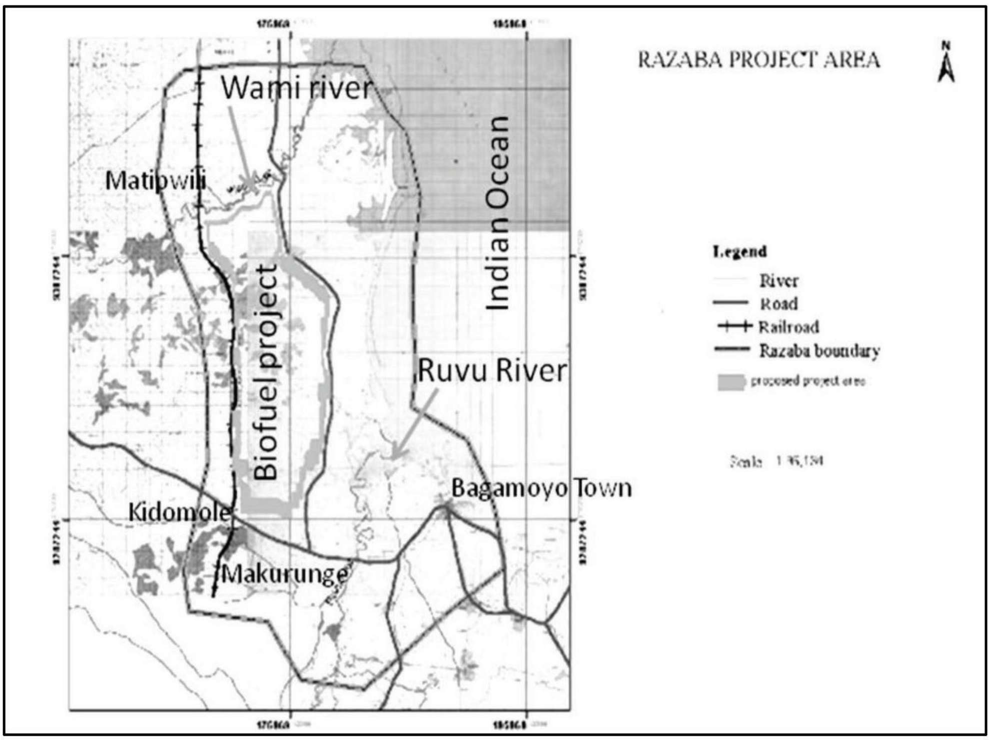


Figure 2. Location of the biofuels project area, the two rivers and relative location of the three villages. Source: SEKAB Bio-energy (Tanzania), 2008:7 (modified)

To analyse the adaptive capacity of local communities to deal with this biofuel project and to make use of potential existing opportunities, three communities were chosen: Makurunge, Matipwili and Kidomole. All three communities depend on subsistence agriculture as their main economic activity, while other economic activities include fishing, beekeeping, hunting and livestock keeping (Tobey, 2007). The three communities have land bordering the biofuel project area. Table 1 presents characteristics of the three selected villages. All three communities depend on firewood and charcoal as their main source of energy for cooking, while their main sources of water are the Wami and Ruvu rivers.

The determinants used to analyse the adaptive capacity of the three communities were outlined earlier (availability of financial resources, access to information and technologies, and quality of institutional arrangements. However, the choice of indicators for adaptive capacity and vulnerability studies is usually confronted with issues of geographical scale, limited understanding, dynamism and complexity (Adger et al, 2004). Implicitly, indicators at a local level setting are different from indicators at national and international level settings. Ideally, the development of indicators at the local scale would also require validation from the stakeholders, i.e. the local communities, themselves (Adger et al, 2004, Brooks and Adger,

Table 1. Demographics of the three studied villages.

	Makurunge	Kidomole	Matipwili
Area (ha)	56,830	6,877	28,331
Number of inhabitants	2,079	866	3,549
Ethnic composition	Wakwere, Wadoe, Wazigua, Wagogo, Wanyamwezi	Wakwere, Wadoe, Wazaramo, Wasukuma, Parakuyu, Barbaig	Wakwere, Wadoe, Wanyakyusa, Wazaramo, Wagogo, Waluguru, Wachagga
Number of primary/secondary schools	2/1	1/0	2/1
Description	Close to Bagamoyo town, borders both Wami and Ruvu rivers, with a fishing community at Mtoni hamlet. Engaged in subsistence agriculture, fishing, trade (small businesses), and livestock keeping	Remote, residents mainly engaged in livestock keeping and agriculture as their main economic activities	Remote, highly inaccessible especially during the rainy season. Principally engaged in agriculture, business and fishing. Borders Wami river

2005). However, this could not be applied in this study due to time and resource constraints, and instead the indicators were validated through literature and expert reviews. Thus, in order to measure them, proxy indicators were defined for each determinant, as summarised in Table 2.

To assess the defined proxy indicators in the field, a combination of qualitative and quantitative data collection methods were applied. Brooks and Adger recommend the use of this method in assessing social ecological systems, using indicators of adaptive capacity to an external disturbance, such as flood (Brooks and Adger, 2005).

The three selected villages, together with their sub-villages and the biofuel project area, form the social ecological system under study. These villages are adjacent to the biofuel project and thus are the ones most likely to be affected by the short and long term impacts of the proposed project (Brooks and Adger, 2005). Moreover, the three villages are located within the lower part of Wami/Ruvu basin, which heightens their vulnerability to floods and other catastrophes. Random sampling was employed to select 30 households from each of the three villages, resulting in a total survey sample of 90 households. The sample size of 30 households for each village was chosen to allow for some inferential statistical analysis, reliability and validity, while a larger sample was not possible due to resources and time constraints. The following section provides an analysis and discussion of the main findings of the study, organised according to the three categories investigated in the study as influencing adaptive capacity. Emphasis is placed on the significance and implications of these findings in relation to the adaptive capacity of the villages.

Table 2. Categories and proxy indicators used to assess the adaptive capacity of the three studied communities.

Category	Proxy indicators used
Availability of economic resources	- Main economic activities, e.g. agriculture, fishing, livestock keeping, small businesses, hunting and formal employment – e.g. in the biofuel project - Access to credit facilities - Average income per year per household head - Emigration, remittances - Livelihood diversification activities
Access to information and technology	- Access to information on climate change and biofuels, e.g. presence and ownership of newspapers, television, radio and mobile phones at household level - House quality e.g. brick, mud, poles - Type of roofing material e.g. iron sheets, thatches - Awareness of the benefits of biofuels on climate change - Presence of extension workers (agricultural and livestock government employees working at the village level)
Institutional arrangement	- Land ownership structure e.g. who owns land at household level - Land access for grazing, agriculture, fishing grounds (leasing, personal ownership, no access) - Membership in community groups/organisations - Changes in land access over time - Participation in land allocation and negotiation processes, especially with investors - Participation in the decision making process at the village level - Presence of formal and informal networks

RESULTS AND DISCUSSION

Availability of economic resources

The study revealed that the poor economic situation of all of the three analysed communities makes them vulnerable to external changes, although this was partly compensated by relatively diversified income strategies. Historical profiles indicate that the villages suffered from the consequences of the villagisation programme implemented in 1973. Villagisation is defined as the grouping of populations in centralised planned settlements in order to facilitate the provision of basic social services such as education and healthcares (Lorgen, 1999). In all sampled villages, the programme disrupted their traditional agricultural production activities and seriously affected food security in the area.

Two thirds of the community depend on subsistence agriculture for their main source of income. The various sources of average household income per year varied significantly within and between the three villages ($F=12.11$ $P \leq 0.05$); (Figure 3) largely as a result of the differences in the relative location and accessibility of each of the villages. However, subsistence farming does not guarantee a sustained flow of income throughout the year in any of the three villages. This becomes even more critical when climate change impacts are considered, as the occurrence of more frequent and more extreme droughts is expected to rise. In addition, fishing stocks were reported to be on the decline. This has a large impact on the communities as they already suffer from limited access to fishing grounds and a lack of adequate and modern equipment for more effective fishing. The few existing credit opportunities have not improved this situation .

Only 3% of all interviewed people were employed, indicating a nearly complete absence of local opportunities for paid employment. The only relevant employer in the region was the salt company Sea Salt in Kitame, Makurunge village. In this situation, linkages to family members in the villages were an important factor to supplement the communities' income and enhance the adaptive capacity. Analysis revealed that emigration influenced the availability of remittance in the study area ($\lambda^2=0.00$, $P \leq 0.05$). Remittances tended to cushion household incomes especially in rural areas in times of stress, such as severe droughts, floods or diseases.

In terms of income sources as related to gender, the results indicate that men have more diversified sources of income than women ($\lambda^2=0.027$, $P \leq 0.05$). This indicates a common phenomenon in the dominant patriarchal system that gives the household head, usually the male, more income sources options than the female. For instance, males are engaged in agriculture, trade, hunting and fishing, while females are restricted to subsistence agriculture and household chores. Equitable distribution of resources is critical in enhancing adaptive capacity and thus gender disparity in the sources of income among households and within the community represents inequitable distribution of resources and hence a weaker adaptive capacity(Smit and Pilifosova, 2001). Kelly and Adger (2000) argues that increased inequality within a community increases 'collective vulnerability' (hence decreasing adaptive capacity); and there are usually strong links between inequality and lack of diversified sources of income, placing further constraints in adaptive capacity.

Table 3 summarises the analysis of the proxy indicators for the availability of economic resource on adaptive capacity in the study area. This analysis indicates that, the economic situation of the local communities makes them more vulnerable to external changes, although diversified income suggest a strong adaptive capacity.

Table 3. Summary of the analysis of proxy indicators for the availability of economic resources.

Indicator	Analysis: strong (+) or weak (-) adaptive capacity
Main source of income	-
Income diversification	+
Gender distribution of income sources	-
Village location	-/+
Access to credit	-/+
Remittances availability	-
Formal employment	-
Famine/drought/floods	-

Access to information and technologies

Although the three communities have a weak adaptive capacity, as indicated by the analysis of the three determinants (Table 4) they also showed significant indigenous knowledge on climate variability. This knowledge has been accumulated and embedded into the SES over a long period of time (Gadgil et al, 1993) and includes knowledge on local weather patterns which has guided the community's day to day livelihood activities. Communities in the study area demonstrated a high level of understanding of climatic change and its effects on their social ecological system over time. This was demonstrated during the construction of historical profiles in focus group meetings, as well as in the interviews with the elderly, influential individuals. However, there was a complete lack of awareness about how decisions on climate change mitigation are being made at national and international levels, including political decisions about the production of biofuels.

With regards to the use of modern communications technology, results show that at least 67% of the respondents possess both a radio and a mobile phone. The use of mobile phones has affected the way in which people interact in many parts of Africa, and it is now considered an important factor in strengthening communication and the

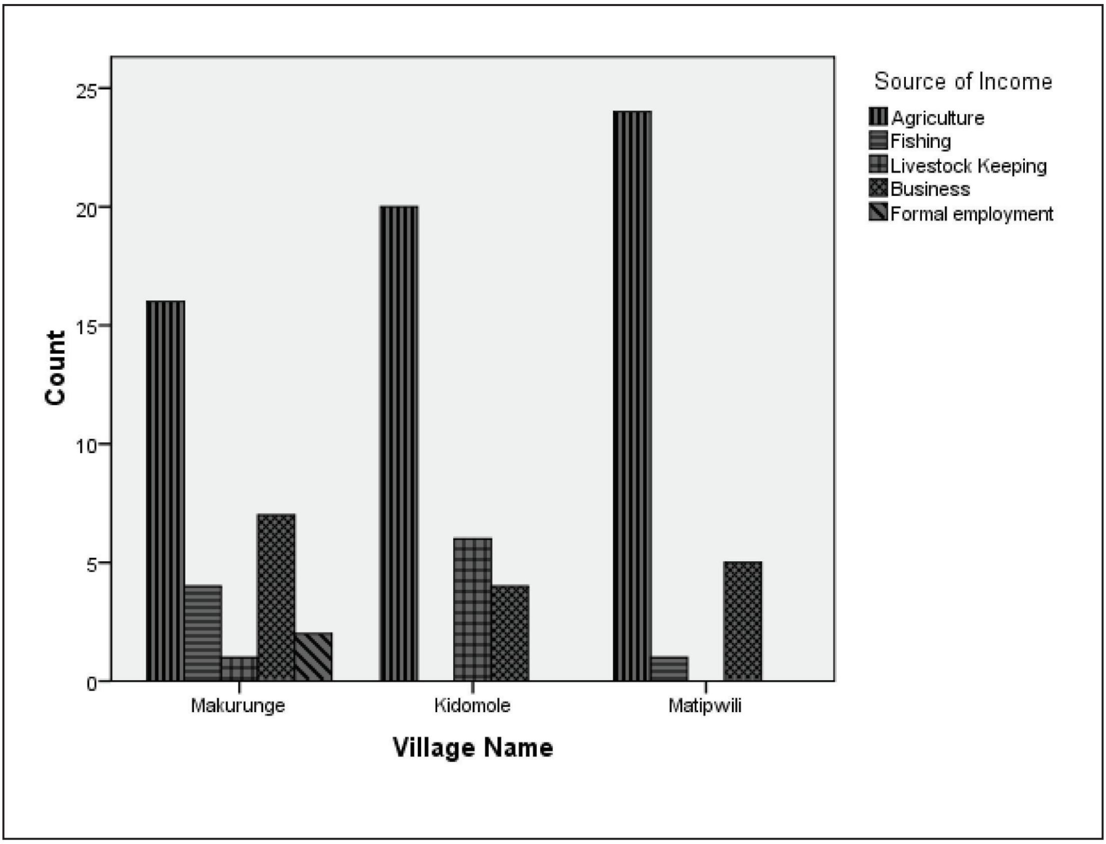


Figure 3. Distribution of income sources among Makurunge, Kidomole and Matipwili villages.

institutional environment (Nelson et al, 2008). Considering rural-urban migration, mobile phones facilitate and ease communications between individuals in rural and urban centres, as reported during interviews and focus group discussions. Table 4 provides a brief summary of the influence of information and technology in the adaptive capacity, indicating a general lack of information on biofuels and its benefits and poor infrastructure quality.

Institutional arrangement

In general, institutional arrangements (both formal and informal) affects, inter alia, decision making processes and structures, participation, organization and access to resources. In the study area, land ownership and access at household level don't seem to cause any major problems such as conflicts over use. However, information from focus group discussions and participatory village mapping indicates the presence of investors who have obtained large pieces of land, and the rush for more land still continues. Four investors were identified in Makurunge village as large scale land owners. These were AZANIA farm (since 1984), JENETA, SEKAB and Warioba farm. In Kidomole village, it was reported that a private company has filed an application for village land to grow sugar cane for biofuel. This conflicts with the practice in the country which requires that investors channel their applications through the Tanzania Investment Centre (TIC). In Matipwili village, land ownership has changed over time, from free access to controlled land access and ownership using regulations and procedures. Furthermore, conflicts over land use were reported between Matipiwli village and Saadani National Park regarding Kisauke area that was annexed to the park without proper compensation to the communities. Regarding the quality of institutional arrangements, the local institutions showed some strength with regard to land tenure schemes and informal networks. However, it also became obvious that the identified local institutional arrangements were completely ignored at the national level. This mismatch between local and national level institutions seriously diminished local institutional capacity to adapt. For example, all three communities reported that they had not been consulted regarding the changing of ownership and access rights in the now SEKAB project area. A study by Adger (2000) in coastal Vietnam indicates how land privatisation may exacerbate vulnerability (even in the absence of changes in the profile of the physical hazard such as floods) and reduce adaptive capacity as a result of institutional change.

The interviewed fishermen, especially in Matipwili village reported a decline in water flow in the Wami river, a claim which has been reported in various studies (see, for example Tobey, 2007). Further analysis indicates that their complaints are compounded by the fact that they have now limited access to the fishing grounds in the village, previously a common pool resource. The fishing grounds are now part of the area that has been leased to an investor, Kisampa lodge. Fishermen must have special permits to fish in the area. However, the literature in property rights shows that common pool resources are best managed under a common property regime as a way of privatising common pool resources to a certain group of people without parcelling up the resource (McKean, 2000; Young, 2002; Dolsăk & Ostrom , 2003). The conflicts on land use change as witnessed in Matipwili village and Saadani National Park is another indication of a weak adaptive capacity. The declaration of the former Saadani Game Reserve into a national park (SANAPA), a process which started in 2002, marked a major institutional change in terms of not only how the area's resources would be managed but also the reappearance and manifestation of long held conflicts between the village and conservation authorities. Table 4 provides a summary of the institutional analysis with regards to its influence on the adaptive capacity of the local communities.

Table 4. Summary of the analysis of proxy indicators for institutional arrangements

Indicator	Analysis: strong (+) or weak (-) adaptive capacity
Communication devises (mobile phones, radio)	+
Access to information (newspapers)	-
Information on climate change	-/+
Information on biofuels and benefits	-
Infrastructure quality (roads)	-
House quality	-/+
Indigenous knowledge on climate change	+
Presence of extension workers	-
House building strategy	-/+

CONCLUSION

Climate change and its impacts is arguably one of the most significant threats the world is facing at present and even more in the future, if serious measures to reduce it are not undertaken. However, some of the proposed mitigation measures such as biofuel production may compromise the adaptive capacity especially of rural communities in developing countries.

This paper has attempted to provide an explanation of how climate change mitigation measures may affect the adaptive capacity of a given SES. In particular it explores the question of whether adaptive capacity of rural communities is sufficiently high to deal with the challenges (threats and opportunities) of biofuel projects. The findings, generated by the assessment of three villages in rural Tanzania- currently affected by a biofuel project indicate that biofuels projects may negatively affect poor rural poor. This is especially so when these projects are implemented without adequately considering characteristics of the SES in temporal and spatial dimensions. In this regard, determinants of adaptive capacity are important in deciding whether and how to bring new investments in these areas, and prior assessment of the same is critical before any intervention.

The potential impacts of the project to environmental resources, especially the Wami river and its estuary deserve an independent study as this could not be covered in this study due to time and resources constraints. While there is a reported decline in flow of Wami river, the biofuel project intends to draw water from the same for irrigation of its sugar cane plantation, estimated at 0.59m/s3/day (SEKAB, 2008; Tobey, 2007). However, this is not compared with the actual available water for use in the river and how this use would affect other users based on environmental flow analysis. It is likely that further water withdrawal will compromise the ecological integrity of the park in terms of water availability to wildlife and salt intrusion from the Wami estuary.

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TANZANIA POLICY REFORMS: WHAT LESSONS CAN WE LEARN FROM MANAGEMENT OF WETLANDS ECOLOGY?

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ABSTRACT
Wetlands are the most precious form of ecosystem that we have in the world. Wetlands contribute to biodiversity, clean water, flood control and habitats for millions of species of flora and fauna. Despite all these services, wetlands still face major challenges of mass destruction, like many other natural resources. The facts that policy reforms that Tanzania initiated from the early 1980s that did not pay attention to wetlands management have even caused more threat to the country's wetland ecosystems. In fact, with policy reforms the new models of development were emerged, became popularly known as the Structural Adjustment Programmes (SAPs) stressed for efficiencies of the free-market allocation of resources and emphasised deregulation and export orientation so as to achieve international competitiveness based on the comparative advantage. The model thus supported the notion of globalism or one world in which a single market for goods, capital, services, skills and technology prevails with a private sector occupying a central role. To this end, the emphasis on private sector mainly on wetlands has contributed to destruction of wetlands in many parts of developing world, Tanzania in particular. A private sector that is not strictly monitored is only driven by profit motive at the expense of anything could even cause more destruction. Thus, this paper aims at examining how policy reforms have influenced activities in the wetlands in Tanzania and the destruction caused with specific reference to Lakes Tanganyika and Victoria. Specifically the paper examines the extent of how the expanded fishing activities under the influence of policy reforms had not paid attention to conservation goals and how it has affected wetlands in the two Lakes. Attention was paid to some few fishing beaches along both Lakes Tanganyika and Victoria with view to highlighting how wetlands have been marginalized by expanded fishery activities that threaten ecology of the wetlands.

Keywords: w*etland, SAPs, policy reform*

INTRODUCTION
In the late 1970s there was a major global change in many policy reforms that was characterised by a global economic recession. High interest rates, declining commodity prices, internal and external imbalances in developed countries, these

had created adverse conditions for the developing economies by the beginning of the 1980s (Bagachwa and Limbu, 1995). At the same time, the developing world was experiencing endemic economic disruption arising from distortions and inefficiencies which had crippled their production, distribution and financial systems. For most of the developing world, Sub-Saharan African countries in particular, the 1980s was a lost decade. Problems experienced were not only rendered many of the developing economies dysfunctional but also created space and opportunity for the emergence of a new global development paradigm.

A new turn in economic thinking and policy- making took place. When the world recession began to unfold in the mid-1970s a number of analysts and decision-makers, spearheaded by the International Monetary Fund and the World Bank, attributed the recession to the predominance of welfare-oriented (basic needs) programmes and the neglect of real economic concerns (Bagachwa and Limbu 1995). In several countries, the perception of the government as the driving force of economic growth was giving way to new thinking which advocated an increased role for market forces in the allocation of resources and a much enlarged role for the private sector in the production process and the management of the economy.

To this end, the new model of development that emerged and became popularly known as the Structural Adjustment Programmes (SAPs) stressed the efficiencies of the free-market allocation of resources and emphasised deregulation and export orientation so as to achieve international competitiveness based on the comparative advantage. The model thus supported the notion of globalism or one world in which a single market for goods, capital, services, skills and technology prevails. The new focus was on structural adjustment as precondition for growth and implicitly for poverty reduction. The Newly Industrialising Countries (NICs) provided good examples for this paradigm. Their success was perceived to lie in developing strong export-oriented manufacturing sectors. This led to the belief that other developing countries could achieve similar successes, provided they were able to stabilise and restructure their economies.

In all, 29 Sub-Sahara African countries (apart from South Africa) implemented Structural Adjustment Programmes between 1982 and 1986 (World Bank 1994a). With respect to Tanzania, the adoption of the Economic Recovery Programmes reflected to a large extent, this shift in the world opinion. Until the mid-1980s, development policies and the production system and export regime tended to discriminate against private sector development and exports, and chiefly benefited public sector agencies and import-substituting firms. However, since the adoption of the reform programmes there has been a policy reversal. A notable feature has been the policy emphasis on the restructuring the supply side of the economy from an inward-oriented import-substitution strategy towards an outward-oriented export-led growth strategy. The new policy advocates an enhanced role for the private sector and the shift of resources from non-tradable by changing the structure of incentives through exchange rate adjustment, changes in the domestic prices, and the relaxation of wage-control policies.

Objectives

- examining how policy reforms have influenced unsustainable activities in Tanzania wetlands
- examining the extent of how the expanded fishing activities under the influence of policy reforms had not paid attention to conservation goals and how it has affected wetlands in the two Lakes (Victoria and Tanganyika).

METHODOLOGY

This paper tries to identify the different stages of policy reforms that Tanzania has had adopted and thereafter an analysis on how the reforms have influenced activities in the wetlands is discussed with specific reference to fisheries in Lakes Victoria and Tanganyika. An attempt to show how policy reforms have influenced expanded fisheries activities that have compromised with the wetlands ecology in the landing sites is well discussed. Thus, the paper focuses more on literature review with short visits the employment Participatory Rural Appraisal (PRA) methodology along lake shores of both Victoria and Tanganyika.

Study area

The case study areas were chosen along the landing sites of Lake Victoria and Lake Tanganyika. The landing sites along Lake Victoria were Igombe and Kijiweni located in Ilemela and Sengerema districts respectively; while those located along Lake Tanganyika are Katonga and Kibirizi both located in Kigoma municipality.

Structural Adjustment Programmes

The modest macroeconomic performance that Tanzania achieved until the mid 1970s was completely wiped out by the unfavourable external conditions which led to the crisis period between 1980-85, that had never been experienced (Ndulu, 1989).

During the early 1980s, Tanzania economic performance deteriorated considerably. Despite all efforts under the "African Socialism" in the name of "Ujamaa", Tanzania's economy remained largely inefficient, resulting in low growth rates and poor product quality by international standards. Indeed, GDP growth rates for 1981 and 1983 were -0.5 and -2.3 percent respectively (Mbele and Mashindano, 1995).

Moreover, the extremely overvalued exchange rate decreased the country's competitiveness in the meagre traditional export commodities, thereby diminishing export earnings. In addition, Tanzania's terms of trade deteriorated severely in the early 1980s due to collapse of the world market prices. Consequently, the trade deficit increased, foreign capital inflows decreased and overall indebtedness exceeded critical levels. This poor performance of the economy forced the country to reconsider its development strategy away from policies of "Ujamaa".

In response to declining economic performance, Tanzania launched its first and self-guided National Economic Survival Programme (NESP) in 1981. The objectives of this programme, among other issues, were to liberalise the economy; however NESP failed because of retaining the previous "African Socialism" economic regime. Nevertheless, in 1982 the government adopted a three-year Structural Adjustment Programme (SAP) that was prepared in collaboration with cooperation of the World Bank but based on suggestions of the Tanzania Advisory Group.

Again, this was an exclusively national effort; it was a home-grown SAP, without any World Bank or IMF support. On the whole, SAP did not achieve significant changes in improving economic performance because the government was very reluctant to implement the policy reform measures. It was not until the fiscal year 1984/85 that Tanzania launched its first significant reform with commitment to liberalising the economy. It is at this juncture the policy of "Ujamaa" in the name of "African Socialism" started changing towards a liberalised free-market oriented economy. The reform package, among other issues, contained the following main policy measures (Wobst, 2001):

- Agricultural producer prices were raised by 46-55 percent;
- Tanzanian shilling was depreciated by 40 percent;
- Domestic trade of food products were liberalised;

Although the international donor community welcomed these measures as a first step in the right direction, they only marginally improved the overall economic performance. Furthermore, international organisations increased their pressure on Tanzania's government to take further actions and pursue a strict coordination of its economic policies. It was not until 1986/87 fiscal year when Tanzania officially accepted and implemented externally initiated Economic Recovery Programmes (ERPs). Since then Tanzania development strategy has been the liberalisation of all sectors of the economy, so as to achieve a sound, self-sustaining economic growth.

Externally Supported Reform Programmes

The reforms which were initiated by the government did not work properly as anticipated, thus paving the way to externally initiated reform programmes, which forced Tanzania into reaching an agreement with the IMF and the World Bank in 1986. Following this agreement, a three-year Economic Recovery Programme (ERP) 1986/87-1988/89 was announced in the 1986/87 budget.

The ERP's medium-term objectives were towards positive growth rate in per capita income, a GDP target growth rate of 4.5 percent, an inflation rate below 10 percent in 1988/89, a fiscal government deficit below 13 percent of GDP, an adjustment of the exchange rate toward an "equilibrium" exchange rate by mid-1988, an increase of between 30 and 80 percent in nominal producer prices for cash crops, and a decontrol of domestic prices over a period of three years (URT 1986). The objectives of the ERP were incorporated in the 1988/89-1992/93 five-year development plan and were reinforced by the Economic and Social Action Programme (ESAP) in 1989. Within the scope of the two programmes, the government strove for a general reduction of state controls and the promotion of private sector activities. In this context, it declared the rehabilitation of key infrastructure components a priority to support future economic development, especially transportation facilities like roads, railways and ports. The economy initially responded positively with an average annual GDP growth rate of around 4 percent during 1986-94.

However, during the period (1990-95), the government showed a much lower commitment to reforms, which led to deteriorating macroeconomic management, and performance, and instability. In reaction, the IMF, World Bank, and most bilateral donors sharply reduced their support, suspended payments for development projects and balance of payments assistance, and refused any further assistance (World Bank, 1999a)

In 1995, the first presidential and parliamentary multiparty elections were held and President Benjamin William Mkapa was elected. His government immediately approached the IMF to revive Tanzania's economic reform efforts of the late 1980s, which resulted in Tanzania's acceptance of the obligations of Article VIII, Sections 2, 3, and 4 of the IMF Articles of Agreement, effective from July 15, 1996 . By signing Article VIII, Tanzania regained the confidence of the international donor community in its serious commitment to pursue sound economic policies. In November 1996, the IMF approved a three-year credit under the Enhanced Structural Adjustment Facility (ESAF) to support Tanzania's new ERP for 1996/97-1998/99. The new ERP emphasised fiscal performance and structural reforms, namely:

- Maintaining a stable fiscal stance and using public resources more efficiently;
- Promoting the private sector by deregulating investment and divesting parastatals;
- Providing greater support for primary education and basic health care
- Supporting the development of basic infrastructure, especially to give impetus to rural agricultural development;
- Restructuring the financial sector to respond to the needs of the private sector (Wobst, 2001).

Poverty Reduction Strategic Paper (PRSP)

Like other Sub-Saharan African countries, Tanzania has been in the process of replacing previous structural adjustment policies and conditionality by the Poverty Reduction Strategic Paper (PRSP), as well as parallel initiatives promoted by the donor community. These initiatives include the move from project to programme funding, fiscal stance pursed through a rolling Medium Term Expenditure Framework (MTEF), coordination between donors, sector wide approaches and decentralisation of local government (Ellis and Mdoe 2002).

Tanzania started to move in the direction of a comprehensive poverty reduction in the mid-1990s, and adopted a plan entitled the National Poverty Eradication Strategy (NPES) in 1997. The status and the role of this plan subsequently became somewhat confused, because not long after its publication Tanzania began to be drawn into the PRSP process, whereby the preparation of a PRSP and its acceptance by the donor community became a precondition for debt relief under the Highly Indebted Poor Countries (HIPC) initiative.

The PRSP was published in October 2000, just seven months after the consultation and preparation process was initiated. It contained the required outcome of the consultations with stakeholders and came up with a list of constraints such as poor roads, lack of credit, lack of farm inputs, poor education and health facilities, lack of accountability at lower levels of government administration (URT 2000b). It then sets out a three-pronged poverty reduction strategy for addressing these problems as comprising:

- Sector strategies and decentralisation;
- Macroeconomic stability and reforms;
- Poverty reduction itself, broken down into the three subsidiaries goals of reducing income poverty, improving human capabilities and containing vulnerability.

Tanzania qualified for the debt relief under the enhanced HIPC initiative by donor community on November 27, 2001 after the completion of the PRSP report. The donor community welcomed Tanzania's PRSP as an important step forward the process of focusing on poverty as an explicit objective of public policy (IMF and World Bank, 2001).
The resources made available by the debt relief provided under the HIPC initiative were supposed to be allocated to the anti-poverty programmes, as outline in the Tanzania's Poverty Reduction Strategy Paper. Following the debt relief, Tanzania launched an Education Sectors Development Programme with the chief aim of increasing access to schools, particularly in poor and underserved areas. Progress has been achieved, especially at the primary education level. Budgets have been increased and school fees were abolished.

National Strategy for Growth and Reduction of Poverty (NSGRP)
Tanzania developed the successor to its first Poverty Reduction Strategy paper. This strategy is very different and is named the National Strategy for Growth and Reduction of Poverty and it is better known by its Kiswahili acronym of MKUKUTA (Mkakati wa Kukuza Uchumi na Kuondoa Umaskini Tanzania). It is argued that MKUKUTA is strongly outcome focused and has deliberately set out to mainstream cross-cutting issues as integral to the strategy and not as 'an add on'. The MKUKUTA is based

on the achievement of three major clusters of broad outcomes for poverty reduction, namely:

i. Growth and reduction of income poverty
ii. Improved quality of life and social well being and
iii. Good governance and accountability

For each cluster a set of goals were defined with an associated set of operational targets with specific numeric or no-numeric targets and timeframes. For each operational target, the MKUKUTA identifies specific cluster strategies and intervention package to achieve these targets.

Policy Reforms and Wetland Ecology Management

Wetlands are key and most important ecosystem, services provided by wetlands are vital to both fauna and flora diversity in the world. Despite their unlimited services, wetlands still face mass destruction, much like any other natural resources.

Wetland is of considerable important for socio-economic and ecological values they do provide. They form the basis for the livelihood of the surrounding communities (Tumbo, 2007). With increased human pressure, several activities are practiced within the wetland ecosystems. These include crop production, fishing, grazing and other resource harvesting for both commercial and domestic uses. Due to climate variability and extremes, wetlands are increasingly becoming important particularly during the periods of extreme and persistent droughts. More people are engaged in different wetland-based activities to compensate the crop failures in the uplands and thus fight food insecurity.

Due to free market economy that has been brought by policy reforms, groups of peasants and agro-pastoralists have been migrating to wetlands in search of services that includes land and water resources for both cultivation and grazing. Some are forced to be engaged in fishing and in making craft materials from wetland vegetation. However, land in the wetland is limited in terms of size compared to the upland thus unable to accommodate the increasing land demand and its resources. Thus, this shift has caused conflicts among different user groups of wetlands such as crop producers and livestock keepers, fishermen's; this has been viewed as an emerged serious problem in wetland ecosystems in the country (Mwita, 2004).

Since the commencement of structural adjustment programmes in the mid 1980s wetlands ecology management was not an issue of concern. In all the policy reform measures that Tanzania initiated none specifically addressed the issues in wetland ecology. In fact, policy reforms accelerated the destruction of wetlands through the liberalization of the economy whereby forestry resources were exploited throughout the country. Wetlands that had forests cover were exploited and today the lands that used to be wet are now bare lands without any cover. For example, we had a lot of wetlands along the central Railway line all along from Kigoma to Dar es Salaam; but today those wetlands are nowhere to be seen. The forest cover along the railway line was exploited through unsustainable timber harvesting that was not controlled by the government.

Economic growth that Tanzania has been experiencing does not take into account the destruction of wetlands ecology. Deduction of the negative impacts on wetlands and environment at large from Gross Domestic Product (GDP) would give a realistic picture of the economic growth. The economic growth that does not take into account the destruction of natural resources cannot give a true figure of the country's GDP. All natural resources contribute to a great deal to the country's GDP. To this end, for sustaining wetlands ecology and other natural resources, certain percentage of the GDP should be re-invested back in the natural resources with view of conserving them.

Policy reforms had far reaching effects to the management of wetlands in Tanzania. In the course of liberalizing the economy, attention was not given to the protection of wetlands. Over exploitation of forestry resources due to liberalization of the economy that has not been well coordinated and monitored has contributed to increased droughts in the uplands. This has forced the impoverished people to compete for available wetlands. Again, failure of the agriculture produce due to droughts and the rising prices of agricultural inputs brought by policy reforms, have accelerated movement of people and change of land uses from agriculture to fisheries activities for those communities living along lake shores. An attempt in this paper is made to show how fisheries activities in Lakes Victoria and Tanganyika are compromising with wetlands ecology.

Key Findings from Selected Landing Sites

Kibirizi and Katonga landing sites

With respect to Lake Tanganyika fisheries, the study came up with mixed findings on the fisheries activities in the two beaches that were surveyed. In Katonga beach/landing site 18 fishers and 10 fishing gear owners were interviewed and in Kibirizi beach 15 fishers and 5 gear owners were also interviewed. Each fisher that was interviewed was selected randomly out of four fishers that formed a fishing team. To this end,

Table 1: Net Monthly Income Accrued to Fisher and Gear Owners in High Catch Season (in Million Tanzanian Shillings)

	Below 1	1–3	3.1–6	6.1–9	9.1–2	12.1–15	15.1–18	18.1-21	21.1-24	Total
Fisher	1	15	17	-	-	-	-	-	-	33
Gear owner	-	1	4	3	4	-	1	-	2	15
Total	1	16	21	3	4	-	1	-	2	48

Table 2 shows incomes that were generated in low catch seasons. Only 4 gear owners operated at a loss. 6 more fishing gear owners each netted income that ranged between Tshs. 1.01 and Tshs. 6 million. It is only 2 fishing gear owners that each netted monthly income that was above Tshs. 15 million.

Table 2: Net Monthly Income Accrued to Fisher and Fishing Gear Owners in Low Catch Season (in Million Tanzanian Shillings)

	-1 – 0	0.1 – 1	1.1 – 3	3.1 – 5	5.1 – 7	7.1 – 9	9.1 – 11	Above 15	Total
Fisher	5	27	1	-	-	-	-	-	33
Gear owner	4	2	3	2	1	-	1	2	15
Total	9	29	4	2	1	-	1	2	48

Source:survey 2010

It should be noted at this juncture that millions of Shilling that were generated were further re-investing in fisheries by constructing new fishing canoes. At this juncture, it should be noted that in fisher communities in Kigoma along Lake Tanganyika, a fishing gear owner was respected if he owned many fishing boats. It through this re-investment of the money generated from fisheries that compromised wetlands in the landings sites. Accelerated fisheries lead to increased indirect fisheries activities that take place at the landing sites at the expense wetland sustainability. It should well be noted that any commercial activity in fishing beach needs land and the land that is available is wetland. Activities that were found to be destroying wetlands in Katong and Kibirizi landing sites were: boat construction and repairing, construction of residential camps for fishers, morning markets for perishable goods such as vegetables and tomatoes done mainly by women, retail shops, restaurants, and tailoring marts.

Kijiwen and Igombe landing sites

Table 3 shows incomes from Lake Victoria Nile perch fisheries that were accrued to fishing gear owners at Igombe and kijiweni landing sites. The owners of the fishing gears differed in modality they used to pay their fishers. Generally, fishers were paid in six different categories; the income accrued to fishing gear owners followed a similar pattern. The categories are:

- Those that are paid monthly salary
- Those that are given four days in a month to fish for themselves
- Those that are given eight days in a month to fish for themselves
- Those that are paid 300 shilling per each kilogramme caught and landed
- Those that are paid three-quarters of the net income generated
- Those that are paid four-fifth of the net income generated

The first four categories of payment were practised in Igombe beach, while the last two categories were practised in Kijiweni beach. The choice of any monthly payment category in Igombe beach was an agreement between the fishers and the owner of the fishing gears, although the owner of the gears had a more say than the fishers on the category of payment he preferred.

At this juncture, it should be noted that some gear owners were also fishers. This was particularly true for fishers in Kijiweni beach in Sengerema district. That is, all owners of the fishing gears were also part of the fishing teams. This implied that they incomes came from two resources--one source as a gear owners and the other source as a fisher.

Table 3:Net Income Earned by Owners of the Fishing Gear during High Catch Season

Category of respondent in terms of payments	**Net income earned by fishermen per month in (TShs)**								**Total**
	Below 250,000	**250,000-750,000**	**7500,000-1,250,000**	**1,250,000-1,750,000**	**1,750,000-2,250,000**	**2,250,000-2,750,000**	**2,750,000-3,250,000**	**Above 3,250,000**	
Four days	-	-	-	-	5	-	-	-	**5**
	-	-	-	-	9.43%	-	-	-	**9.4%**
Eight days	-	-		2	13	1	-	-	**16**
	-	-	-	3.77%	24.52%	1.88%	-	-	**30.2%**
Monthly salary	-	-	-	-	3	1	-	-	**4**
	-	-	-	-	5.66%	1.88%	-	-	**7.6%**
300 Tshs/Kg	-	-	8	-	-	-	-	-	**8**
	-	-	15.09%	-	-	-	-	-	**15.1%**
Three-quarters	1	5	2	-	2	-	3	2	**15**
	1.88%	9.43%	3.77%	-	3.77%	-	5.66%	3.77%	**28.3%**
Four-fifth	-	2	2	-	1		-	-	**5**
		3.77%	3.77%	-	1.88%	-	-	-	**9.4%**
Total	**1**	**7**	**12**	**2**	**24**	**2**	**3**	**2**	**53**
	1.9%	**13.20%**	**22.6%**	**3.8%**	**45.3%**	**3.8%**	**5.6%**	**3.8%**	**100%**

Source: Field survey 2010

The implications of incomes earned had to do with management of wetland ecology in the two landing sites of Kijiweni and Igombe. The more the incomes were generated, the more wetland ecology was compromise. There were multiplier effects of those incomes that were generated. These multiplier effects led to increased demand for land (wetlands) for the expansion of indirect fishing activities. The pronounced indirect related fishing activities that were found compromising the environment were: construction of residential camps for fishers, fishing canoes construction, farming activities, fish net weaving, restaurants and tailoring marts, trading of various goods including fish (Nile perch) and Sardines. All these activities were destroying the wetland ecology at an alarming rate. Again, the increase in demand for fish was a result of market liberalization that has lead to an insatiable demand for Nile perch in the European Markets.

The free market economy has seen fishing activities in the Lake Victoria and Lake Tanganyika compromising sustainability of wetlands management. The export-oriented fishing industry has in a profound way affected the traditional fisheries and the different groups of people who depended on it. A trend concerning ownership and management of fishing operations is connected to the increased competition among the processing factories to secure adequate supplies of fish to meet an insatiable demand in the western markets (European markets).

Traditional fisheries that existed prior to 1980s have been compromised by the large scale investors. This has been particularly true for the Nile perch fisheries whereby artisanal fishers who were previously engaged in Nile perch fisheries are no longer in the business and have shifted to Sardines fisheries. There has been an intensive fishing of Sardines from Lake Victoria that has further led to overfishing of the species. The major reason for the intensive fishing of both the Nile perch and Sardines emanates from policy reforms that Tanzania has been implementing-- reforms that have not been supporting rural agriculture causing young people to opt for fishing employment that generates quick money on one hand, and reforms that have accelerated the increased demand of the Nile perch in European markets on the other hand. Plate 1 shows how human activities affect wetland ecology at Igombe landing site.

Bilame (2011b) study has also come up with similar findings with respect to wetland ecology. It has been observed that, there has been an indirect expanding fishing activity that is compromising the wetland ecology. The situation has become more acute during moon-phase when some fishers are engaged in vegetable gardening because they could not go for fishing during that period. This implies that more and more wetlands were required for agricultural production and other indirect fisheries activities. As a result this has further compromised the wetlands ecology in the landing sites. Furthermore, Plate 2 shows an example of the expanded human activities along Lake Tanganyika .

Plate 1: Different human activities practiced at Igombe Landing Site, Mwanza

Fishing boats construction was taking place in areas that were once wetlands and since Lake Tanganyika falls within the rift valley, the destruction of wetlands leads to it has no shallow waters. This accelerateds siltation that would have been counterchecked by the natural vegetation found in the wetlands. This problem has caused most of the ships to face difficulties in navigating to Kigoma harbor.

CONCLUSION

Policy reforms with poor management strategies have caused negative impact on wetland ecology with specific reference to some landing sites along lakes Victoria and Tanganyika. Due to policy reforms that Tanzania has been implementing since the early 1980s that did not pay attention to rural agricultural by removing the agricultural subsidies; many young people in the vicinity of the two lakes have been rushing into the quick money earning business of unsustainable fishing. This has indeed led to the demand of more land in the fishing beaches/landing sites; and in course of expanding the landing sites more wetlands have been put into use. Furthermore, there were no deliberate efforts by policy reforms to protect the wetlands. Trading in timber that was allowed by the government from the mid 1980s when SAPs commenced has compromised most the catchment areas in Tanzania. The current drought that Tanzania has been facing is to a large extent explained by this scenario. Again, the economic growth that Tanzania has been experiencing does not take into account the destruction of wetlands and other natural resources at large. Negative impacts on natural resources arising from economic activities should be deducted from GDP to arrive at a realistic figure. To this effect, the value for destruction of wetlands ecology and other natural resources should be deducted from the GDP.

Policy Implications

In view of what has been raised by this paper; mitigation measures to arrest the situation is of paramount importance. These mitigation measures should be reflected in good policies of national interest towards sustaining wetland ecology. These policies, among others, could include:

- Deliberate policy that could address management of wetlands ecology in all the fishing beaches/landing sites. Leaders of the landing sites could be empowered to ensure that along with fishing activities wetlands ecology were protected.
- A need for a policy that could enhance the establishment of Beach Management Units (BMUs) in each beach/landing site that could be charged with overseeing and protecting the wetlands. Indeed, some landing sites along Lake Victoria had BMU but it was only charged with overseeing the cleanliness of fish and the landing sites. BMU were only active in landing sites dealing with the Nile perch fisheries. To this end, a policy that was in favor of establishing BMU in all the landing sites was highly needed.
- Awareness campaign policy that could send massage to fishers and even the local community with regard to wetland ecology management. Awareness campaigns were highly needed with view to informing the local communities and fishers altogether on the importance of protecting the wetland ecology.
- Granting subsidies to the entire agricultural sector with view to retaining young people in the rural agriculture is called up on. This could prevent young people rushing into the fisheries and indirect fisheries activities that have compromised with the wetlands ecology. The removal of agricultural subsidies has not only accelerated fisheries activities in areas located near the lakes but has also accelerated expanded agricultural production in wetlands that have fertile soils that do not need the application of fertilizers. Furthermore, the accelerated fisheries activities are also to blame for the over fishing of the various species found in both lakes.
- Deducting, from GDP, the value for the destruction of wetlands ecology and other natural resources to arrive at a realistic figure of economic growth.

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THE HUMAN CONTEXT OF PROTECTED AREAS IN TANZANIA AND CHALLENGES UNDER CHANGING CLIMATE

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ABSTRACT
Home to remarkable amounts of biological diversity, Tanzania also is a nation of more than 42 million people, many involved in some sort of agriculture or other form of extractive activity that threatens natural habitat and biodiversity conservation. Amid widespread human presence, the Tanzanian government manages nature in a system of protected areas that includes forest reserves, game reserves, national parks, Ramsar sites, village forest reserves, and wildlife management areas. This paper explores the human context of protected areas in Tanzania through analyses employing geographic information system technology, both to gain a better sense of possible threats to these areas from local peoples and to understand the impacts that various levels of restricted use in these areas have on nearby human settlement. Examining data from the most recent available census of population and housing (2002) yields insights on the socioeconomic context a of different protected area categories a decade ago. Results indicate possible pressure that humans can have on Tanzanian reserves, presenting key challenges to biodiversity conservation in the 21st century—namely how to manage natural habitat and associated species in a nation increasingly affected by human use and economic development. Considering potential impacts of climate change, and its dual effects on the human and natural environments, reveals likely future impacts in the form of expanding agricultural activity and changing human settlement that will threaten people and nature alike.

Key words: *Protected areas, biodiversity conservation, human demographics, climate change*

INTRODUCTION
Biodiversity is under threat globally, the rate of species loss reaching levels rarely equaled in the entire history of our planet (Pimm et al., 2008). As researchers, government agencies, non-governmental organizations, and others examine the disappearance of biological diversity, they focus on areas that are priorities for maintaining species and ecosystems (Brooks et al., 2006). In the quest to define priorities for conservation efforts, certain nations emerge as particularly important for containing a disproportional amount of our planet's biological heritage. Tanzania is one such country, home to portions of two biodiversity hotspots (Mittermeier et al.,

2004a), part of one biodiversity wilderness area (Mittermeier et al., 2003), and portions of nine of the Global 200 ecoregions (Olson and Dinerstein, 1998).

Tanzania shares important characteristics with many other nations important to conserving biodiversity. It lies in the tropics, in the portion of Earth where many of the plant and animal species on our planet exist. And it is a developing country, a nation where much of the population has low income, limited access to education, and poor health, as defined by the United Nations Human Development Index (United Nations Development Programme, 2012). The development status of Tanzania is particularly important to conservation, both because of the limited economic alternatives available to much of its population and because Tanzania, as is the case with many developing countries, is witnessing considerable demographic growth. Increasing demand, amidst an economic system dominated by small-scale extractive activities, places pressure on the very natural environment that must support non-human species as well. In such cases, the human presence near important locations of biodiversity creates the conditions for degradation or loss of habitat, loss of key species, or both in the absence of actions designed to maintain biodiversity.

This paper examines the human context near protected areas in Tanzania, localities most important for conserving biological diversity in this East African nation. The focus primarily is on human population near protected areas, as a rough indicator of likely human pressure. The study employs data from the most recent available census of population and housing, in 2002, estimating the number of people living within 10 km of each protected area. The paper considers six main types of reserves, estimating population in close proximity for each category of protected area as well as for individual reserves. It also looks at the nature of the human presence in terms of level of economic activity, number of people engaged in farming, and number of households relying on charcoal or firewood as their main source of domestic fuel—all indicators of potential pressure on reserves. The paper closes with recommendations for prioritizing conservation efforts, by protected area type as well as by individual protected area.

MATERIALS AND METHODS

Tanzania contains a remarkable amount of biological diversity. Statistics now nearly a decade old indicate the presence of more than 10,000 higher plant species, 316 species of mammals, and 229 species of breeding birds (World Resources Institute, 2003). Conservationists have translated these figures into conservation priorities that lie at least partially in Tanzania. For instance, the two biodiversity hotspots alluded to above—the Eastern Afromontane and the Coastal Forests of East Africa—each contain extremely high numbers of total species, many of them endemic to each region (Mittermeier et al., 2004b):

- Coastal Forests of East Africa: 4,000 plant species, 198 mammals, 636 birds, 250 reptiles, 102 amphibians, and 219 freshwater fishes.
- Eastern Afromontane: 7,598 plant species, 490 mammals, 1,325 birds, 347 reptiles, 285 amphibians, and 893 freshwater fishes.

Increasingly, Tanzania relies on protected areas to help conserve its biodiversity. Protected areas are locations on land or in the ocean intended to protect through legal or other means biological diversity, natural resources, or cultural resources (World Congress on National Parks and Protected Areas, 1992). Tanzania is particularly well covered by protected areas, the nearly 800 such localities in 2010 covering 39.6% of its land area (World Database on Protected Areas, 2010) (Figure 1). Tanzania contains 14 different types of protected areas: conservation areas, forest reserves, game controlled areas, game reserves, marine parks, marine reserves, marine sanctuaries and forest reserves, national parks, nature reserves, state forest reserves, village forest reserves, Ramsar sites, village forest reserves, and World Heritage Convention sites.

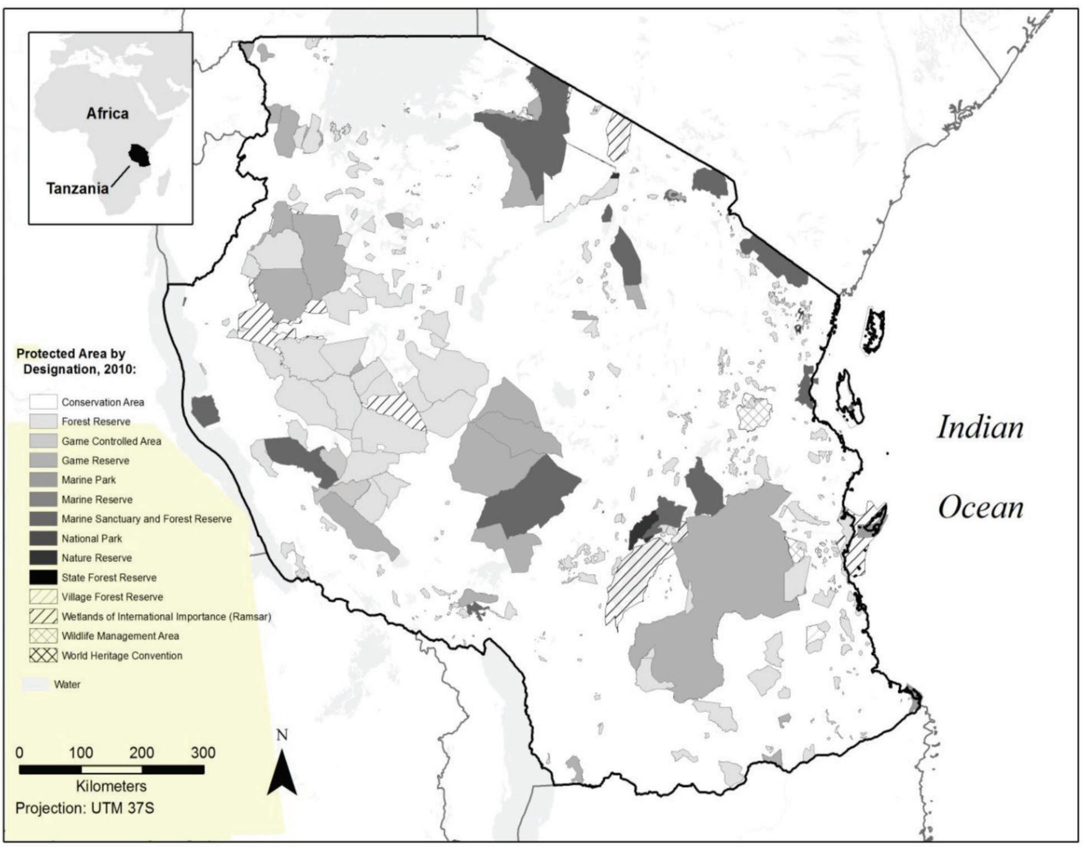


Figure 1: Protected areas in Tanzania

An examination of land cover in Tanzania reveals the importance of protected areas to the conservation of nature. Focusing on land cover designations from the European Space Agency classification for land cover and land use in Tanzania (European Space Agency, 2008) reveals that Tanzania is a combination of natural and modified habitat, the latter often agricultural (frequently combined with natural land cover in some sort of mosaic) (Table 1). Defined at a 300 m resolution, more than 75% of the country is natural habitat of one form or another, with forest (broadly defined) and woodland dominating. However, nearly one-fourth of the country consists of agricultural land use/land cover, a number consistent with the large amount of crop production that occurs in Tanzania. Recognizing the potential of agricultural activity for disruption of natural ecosystems, coupled with the notion that many instances of the small-scale agriculture that characterizes much of Tanzania likely appears as some form of natural habitat, protected areas emerge as essential to the conservation of biological diversity in this nation. The distribution of land use and land cover in Tanzania, and associated pressures on biodiversity conservation, are a consequence the geographic arrangement of people, and vice versa. In 2011, Tanzania contained an estimated 43.7 million, having increased from 34 million recorded by the most recent census in 2002 (National Bureau of Statistics, n.d.; World Bank, 2011). Using information on population distribution in 2002, based on census data in geographic information system (GIS) format, provides a sense of the spatial arrangement of population. The distribution of population was fairly sparse, with occasional concentrations but few high densities (Figure 2). Although one can map population density with some accuracy, researchers currently do not know what density begins to compromise biodiversity, though empirical research in other areas suggest that it may be as low as 10/km2 (Gorenflo, 2011). If this is so, the situation concerning the distribution of human population near protected areas in Tanzania is quite concerning.

Table 1. Land cover in Tanzania, according to the European Space Agency dataset for 2005

Category	Area (km^2)	Percent of Total
Total	966,323	100.00
Broadleaved evergreen tree cover	11,728	1.21
Broadleaved deciduous tree cover	310,501	32.13
Regularly flooded tree cover	371	0.04
Tree cover and other natural veg. mosaic	670	0.07
Shrub cover	192,249	19.89
Herbaceous cover	146,895	15.20
Sparse herbaceous/sparse shrub cover	3,680	0.38
Regularly flooded shrub or herbaceous	2,232	0.23
Cultivated and managed	231,976	24.01
Cropland mosaic	101	0.01
Bare areas	249	0.03
Water bodies	65,473	6.78
Artificial surfaces and associated	198	0.02

Source: GIS calculations based on European Space Agency, 2008

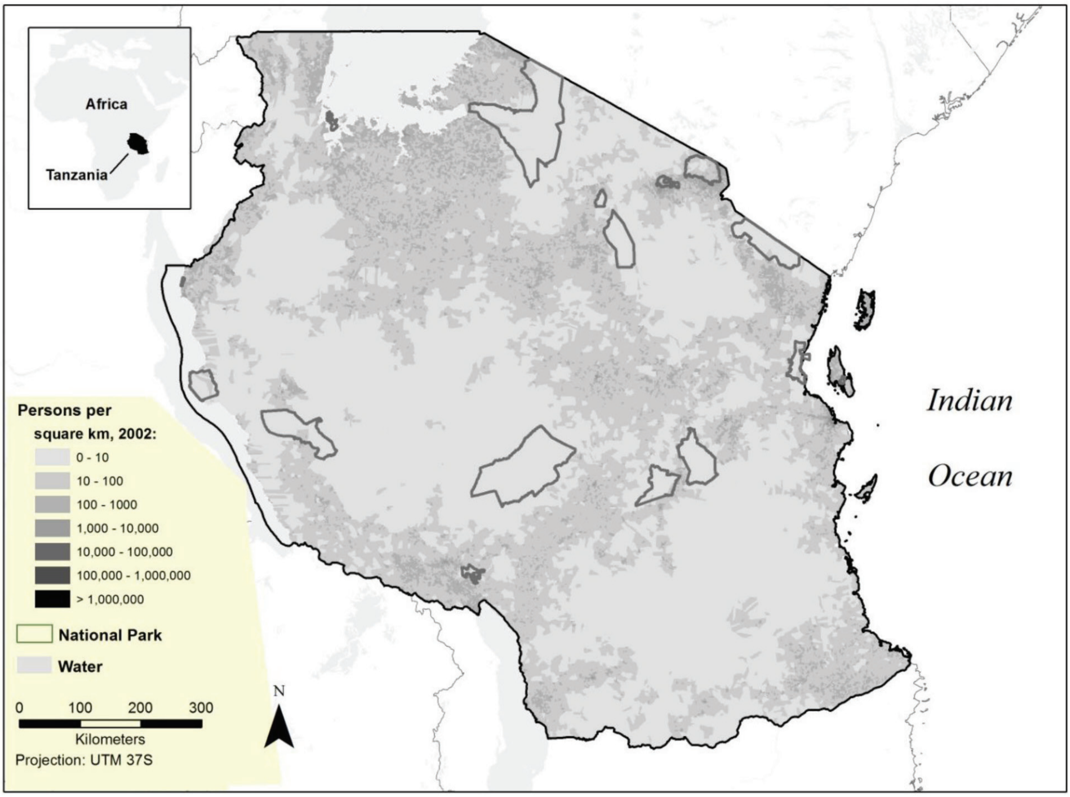


Figure 2: Population density in Tanzania in 2002 with respect to national parks (note: other protected area types not shown due to resulting complexity of map; for general consideration of other protected area types, compare this figure to Figure 1)

A closer examination of one protected area provides a sense of how complicated the situation can be. Udzungwa Mountains National Park is one of the newest national parks in Tanzania. Gazetted in 1992 and covering about 1,900 km2 in the Eastern Arc Mountains immediately west of the fertile Kilombero Valley, despite little indication at a coarse scale of human impacts considerable human settlement and converted habitat occurs in the vicinity of the park (Figure 3). Much of the converted habitat is in the form of agriculture, consistent with statistics for the entire country, though in the case of Udzungwa in the immediate vicinity of this one protected area.

Using GIS technology, one can estimate the number of people who lived within 10 km of protected areas in 2002. Data from 2002 are the most recent available in GIS format, and although nearly one decade old as this paper is written they provide a sense of the level of challenge facing conservation in this East African nation. One can consider10 km as a rough measure of proximity that would allow people, under most conditions, to travel to a PA, use resources, and return home in a single day. Here the focus is on six main types of protected

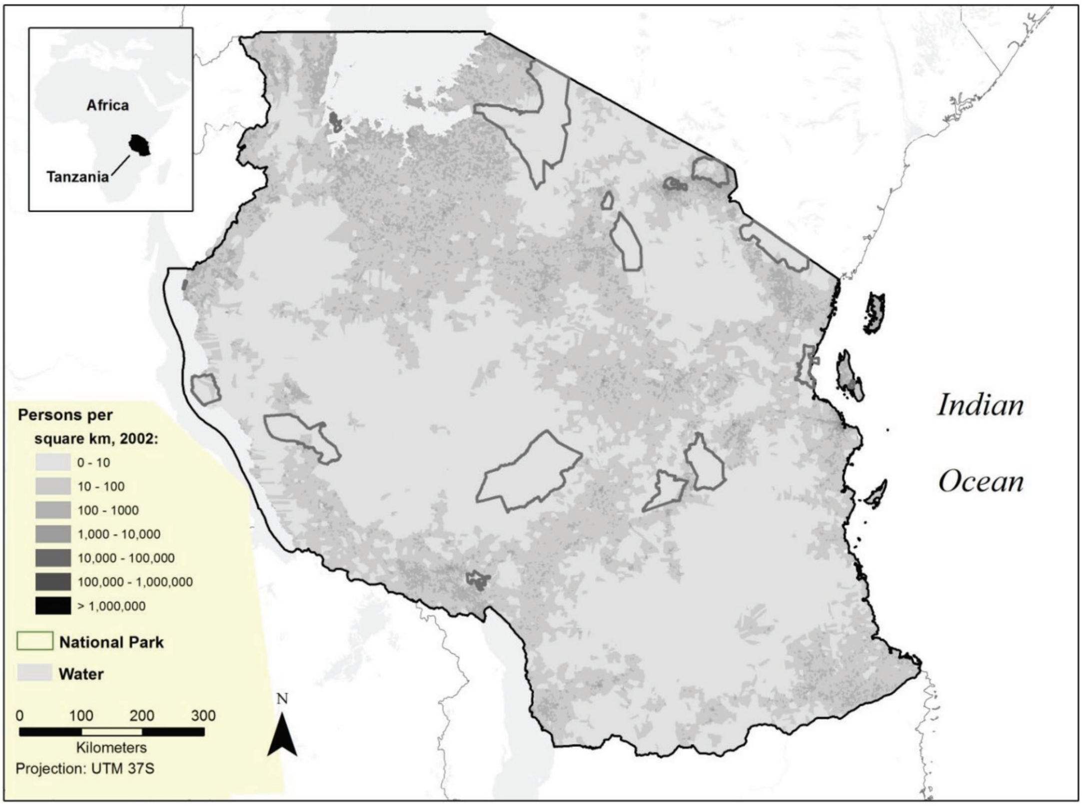


Figure 3: Human settlement and land cover/land use in the vicinity of Udzungwa Mountains National Park

areas, accounting for 96.3% of the total number of reserves and 77.7% of the total area protected in Tanzania (World Database on Protected Areas, 2010): forest reserves, game reserves, national parks, Ramsar sites village forest reserves, and wildlife management areas.

RESULTS

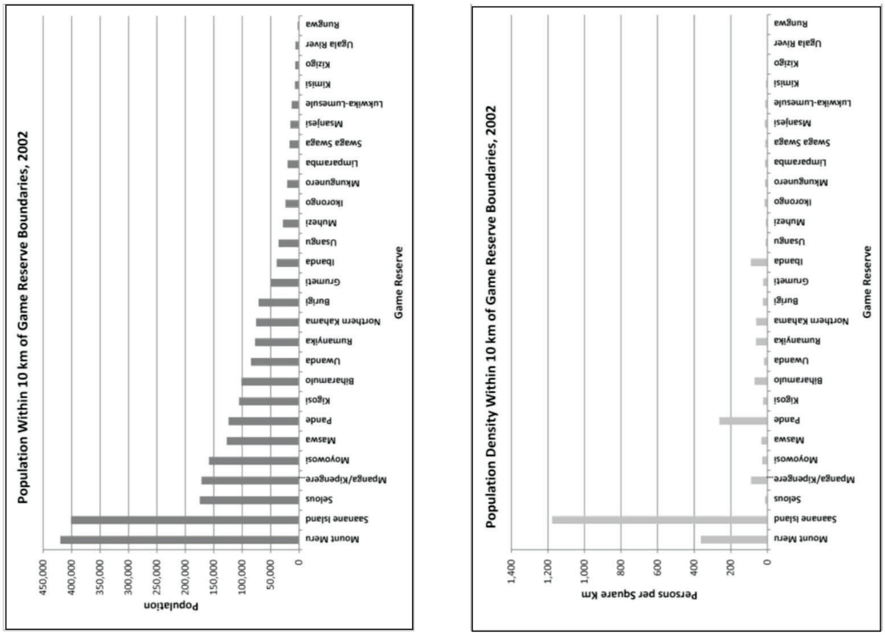
Examining the 2002 census data indicates a remarkably large number of people living within 10 km of the six types of protected areas examined in this study (Table 2). A total of 19.3 million people lived near the protected areas considered, some 57% of the entire national population in 2002. The greatest number of people, in the second highest densities, lived near forest reserves, in part reflecting the large number of forest reserves as well as their location in a variety of settings. Game reserves and national parks each had in excess of 2.1 million people living in close proximity in 2002, the latter registering the highest densities of the six types examined. The reason for the relatively high densities of human settlement in proximity of national parks is unclear, but may in some cases reflect perceived opportunities from close geographic association. The national parks with the highest densities were Kilimanjaro and Arusha,

Table 2. Human Population and Population Density within 10 km of selected types of protected area: 2002

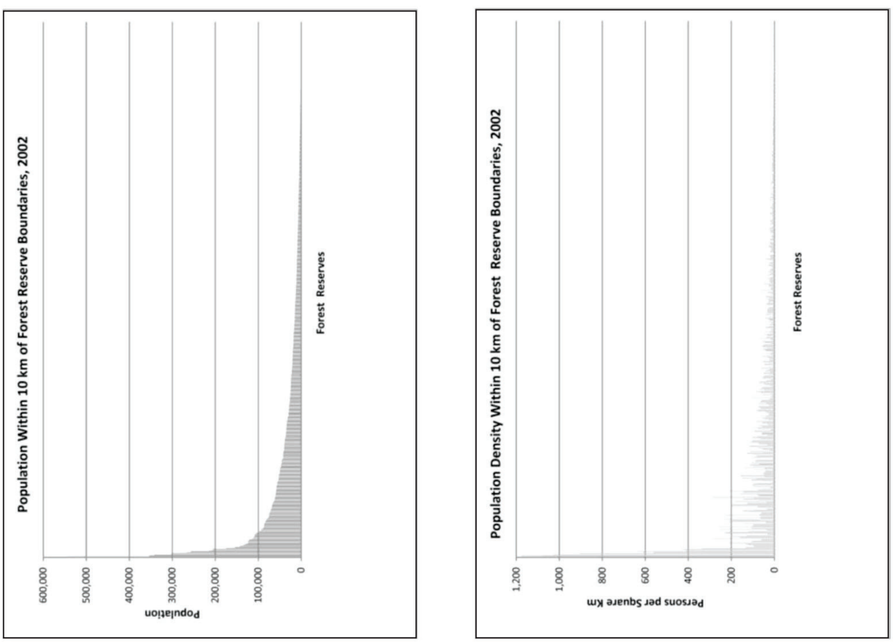
Protected Area Type	Population within 10 km	Population Density within 10 km [a]
Total [b]	19,309,199	39.3
Forest Reserve	13,939,992	41.2
Game Reserve	2,383,186	33.2
National Park	2,194,117	56.7
Ramsar Site	488,577	21.3
Village Forest Reserve	242,775	16.6
Wildlife Management Area	60,552	11.1

both receiving large numbers of visitors and, potentially, experiencing benefits from the high amount of tourism. Other types of protected areas had much lower human presence and population density within 10 km of their borders, though the numbers for Ramsar sites and village forest reserves still indicate many people within close proximity. It is possible to examine demographic characteristics of each type of protected area as well. Figure 4 shows results for each of the six types of protected area. Forest reserves, by far the most numerous protected area type, also had the largest number of people living within 10 km of their boundaries. Presumably maintaining any type of conservation function of such sites, in the face of high human demand in close proximity and with limited management staff to maintain their conservation function, will be an enormous challenge. Population living near other types of protected areas varied, and as their numbers were not so great the 2002 population near each individual area can be shown on the bar charts in Figure 4.

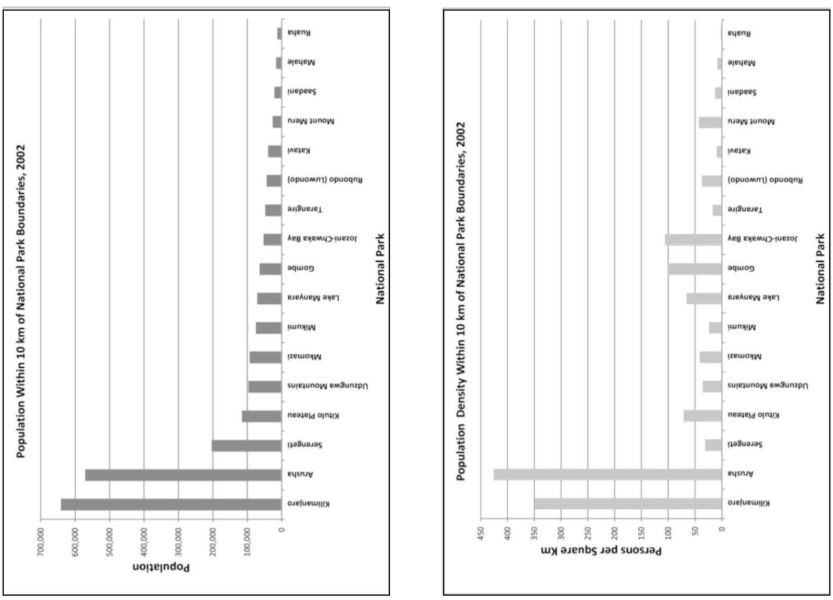
The bar charts in Figure 4 are informative, though one needs to exercise care in interpreting them. For instance, often it is the combination of total population and density that reveals possible concerns, absolute population indicating the scale of human demand and density adjusting for different sized areas within a 10 km-wide buffer. These two measures in a sense represent magnitude vs. intensity, respectively. The Selous Game Reserve provides a good example of the complementary insights from the two measures, the nearly 175,000 people living within 10 km of the reserve's boundary in 2002 representing only about 13.6 persons/km2 due to the enormous size of its geographic extent. Another consideration is that population rarely is distributed uniformly, instead often occurring in denser concentrations, and it is these concentrations that generate the greatest demand, and hence likely the greatest pressure on a given protected area. Because limitations of space preclude presentation of maps showing population distributions, I currently am considering development of a web-based utility that would provide protected area managers in Tanzania with cartographic details of demographic distributions in the vicinity of their parks.


Population Within 10 km of Game Reserve Boundaries, 2002
Population
450,000
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
Mount Meru
Saanane Island
Selous
Mpanga/Kipengere
Moyowosi
Maswa
Pande
Kigosi
Biharamulo
Uwanda
Rumanyika
Northern Kahama
Burigi
Grumeti
Ibanda
Usangu
Muhezi
Ikorongo
Mkungunero
Limparamba
Swaga Swaga
Msanjesi
Lukwika-Lumesule
Kimisi
Kizigo
Ugala River
Rungwa
Game Reserve
Population Density Within 10 km of Game Reserve Boundaries, 2002
Persons per Square Km
1,400
1,200
1,000
800
600
400
200
0
Game Reserve

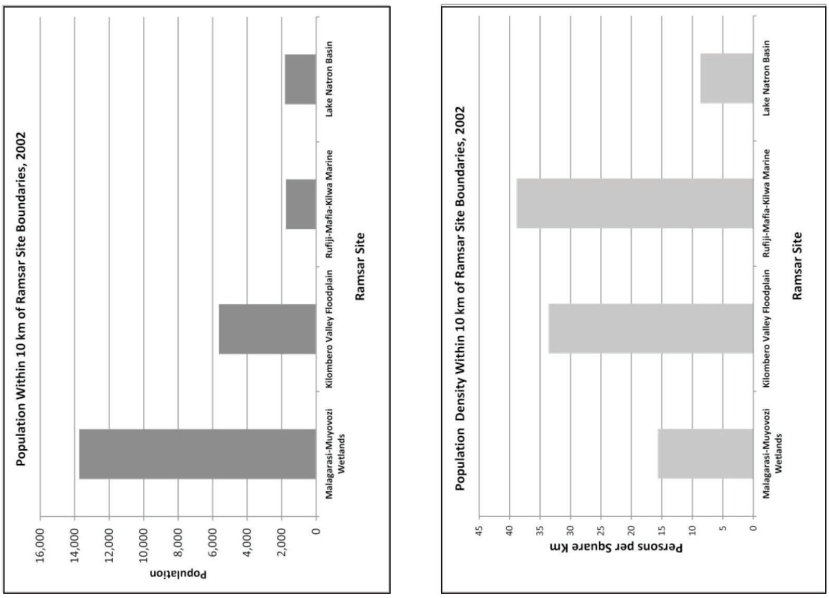
b


Population Within 10 km of Forest Reserve Boundaries, 2002
Population
600,000
500,000
400,000
300,000
200,000
100,000
0
Forest Reserves
Population Density Within 10 km of Forest Reserve Boundaries, 2002
Persons per Square Km
1,200
1,000
800
600
400
200
0
Forest Reserves

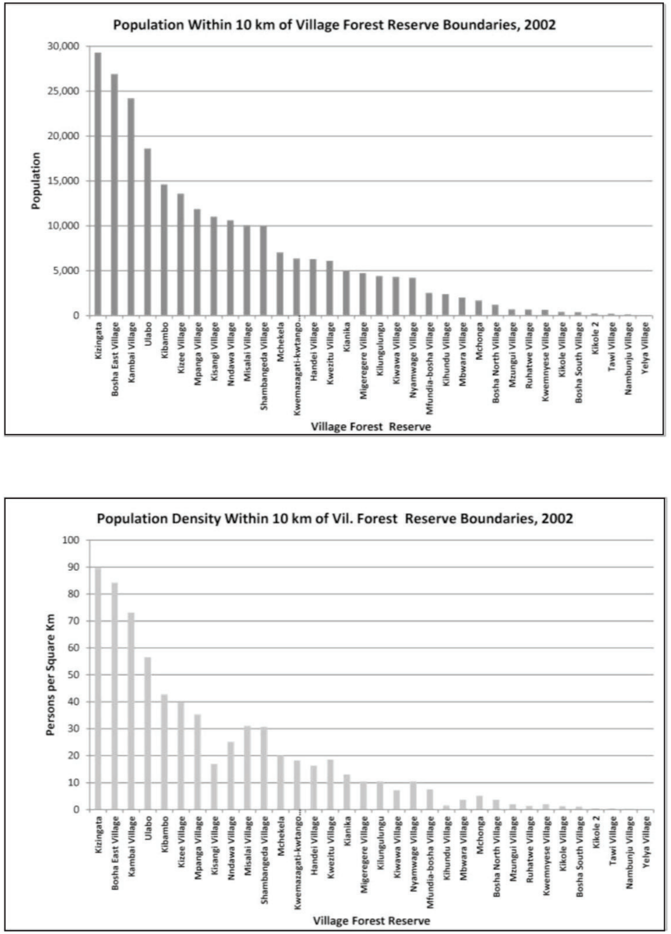
a


Population Within 10 km of National Park Boundaries, 2002
Population
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Kilimanjaro
Arusha
Serengeti
Kitulo Plateau
Udzungwa Mountains
Mkomazi
Mikumi
Lake Manyara
Gombe
Jozani-Chwaka Bay
Tarangire
Rubondo (Luwondo)
Katavi
Mount Meru
Saadani
Mahale
Ruaha
National Park
Population Density Within 10 km of National Park Boundaries, 2002
Persons per Square Km
450
400
350
300
250
200
150
100
50
0
National Park

c


Population Within 10 km of Ramsar Site Boundaries, 2002
Population
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Malagarasi-Muyovozi Wetlands
Kilombero Valley Floodplain
Rufiji-Mafia-Kilwa Marine
Lake Natron Basin
Ramsar Site
Population Density Within 10 km of Ramsar Site Boundaries, 2002
Persons per Square Km
45
40
35
30
25
20
15
10
5
0
Ramsar Site

d



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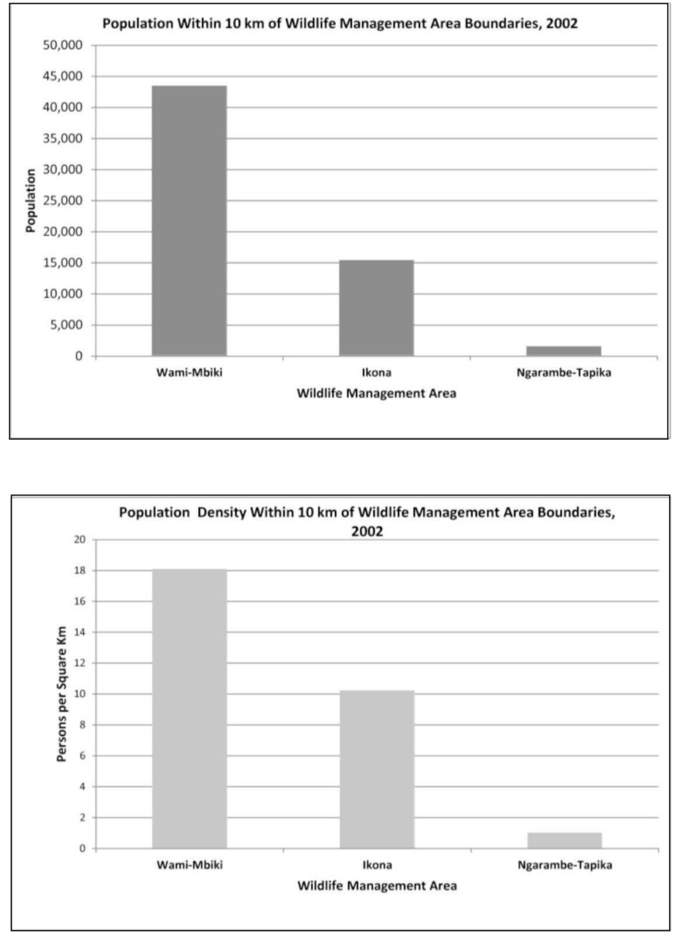

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Figure 4: Population and population density within 10 km of specific types of protected areas: a) forest reserves; b) game reserves; c) national parks; d) Ramsar sites; e) village forest reserves; and f) wildlife management areas

The presence of large numbers of people in the vicinity of protected areas in Tanzania is a concern because of the nature of human activity throughout much of the country. Largely rural, the Tanzanian population relies heavily on local extraction (or production) of necessary resources. For example, 72.3% of the population that reported occupation in 2002 listed farming (based on analysis of the 2002 census data—see National Bureau of Statistics, 2006). Economies often are mixed with a dual emphasis on subsistence, usually emphasizing agriculture, supplemented by activities that generate a small amount of wages, so people live close to the land and extract what they need from it. And a large percentage of households in Tanzania (94.9%) relied on charcoal and wood for fuel in 2002, for domestic use (e.g., cooking) and often for other activities, such as brick-making and local brewing (Nyundo et al., 2006; World Bank, 2009). Such economic patterns and cultural behavior place people in direct competition with other species for necessary resources, and suggest that large numbers of people in the vicinity of a protected area can mean pressure on that protected area.

DISCUSSION AND RECOMMENDATIONS

Conservation of biological diversity throughout the world increasingly occurs amid a large human presence and considerable human use, both often generating substantial impacts on the natural world. Geographic proximity does not always tell the entire story. For instance, in some situations commercial agriculture occurs in regions with fairly sparse populations, responding to more distant demands, though it generates massive adverse impacts on the environment. Similarly, charcoal production often serves urban demands, yet can occur in sparsely populated areas where forests remain (World Bank, 2009). Thus, many local impacts in rural settings are responses to more distant urban demands for resources. Nevertheless, in Tanzania there is considerable local demand near protected areas as well. Resource extraction to support rural populations often occurs in close proximity to those populations, in the absence of extensive distribution systems and the ability to finance such systems, making the occurrence of settlement near reserves a good indicator of pressure regardless of the level of more distant demand.

What one finds in Tanzania is a large number of people living close to protected areas. Although much of the nation has some sort of protected status, the contribution of protected areas to biodiversity conservation in such situations may at worst be compromised, and at best require considerable effort to guarantee protection. Results in this study indicate that forest reserves face enormous local pressures—large numbers of people, often in high densities, near many of current reserves in this category. Forest reserves generally are accorded lower protection than other types of protected areas in Tanzania, and even in cases lacking dense local settlement impacts can be high (Rovero et al., 2005), suggesting that in many cases the analysis presented here underestimates impacts on such sites. In all, despite the large number of forest reserves the contribution of this category of sites to biodiversity conservation may be much lower than first impression.

Other types of protected areas likely contribute more to maintaining biological diversity, though with certain caveats. National parks, for instance, receive the highest amount of protection of any category of protected area in Tanzania. Yet some parks, such as Kilimanjaro and Arusha national parks, have tens of thousands of people living near their borders, often in reasonably high densities. There is a need to focus particularly on protection strategies in such localities. At a minimum, the effective removal of buffer zones from the conservation equation will reduce the effectiveness of the parks. In the worst case, the demands of local people will reduce key resources, biological diversity, or both in the parks, greatly compromising their contributions to biodiversity conservation.

In the presence of high biological diversity, two general strategies emerge (depending on conservation priorities): aggressively protect conservation priorities, or surrender protection to focus on other localities. In the case of the former, if a locality is essential to conservation in Tanzania, steps must be taken to understand and somehow meet human demand, directly or indirectly assisting local communities to meet their needs without inflicting damage on the locality in question. In the case of the second strategy, when conservation costs exceed benefits and localities are not essential to carefully defined conservation objectives, the most practical option may be to remove protection (at least of biodiversity) of some localities in favor of others with more potential for success. National parks and, to a certain extent Ramsar sites, wildlife management areas, and (possibly) game reserves, are classes of protected areas that may fall under the first strategy, depending on the contribution of individual localities to biodiversity conservation goals. Forest reserves, and possibly village forest reserves, may fall under the latter, the former because of the huge volume of human demand located in close proximity and the latter because of decentralized management which makes overall coordination of conservation efforts difficult or impossible.

Climate change in Tanzania has great potential to complicate an already difficult situation in the vicinity of protected areas. Although current methods do not support the projection of local conditions, anticipated changes in East Africa include higher temperatures, increased precipitation during rainy seasons, extended dry seasons, increased unpredictability of wet and dry seasons, and more frequent and intense severe weather events (Case, 2006). Such changes will have implications for all Tanzanians, in the case of subsistence agriculturalists and pastoralists greatly decreasing food security as crop production and animal husbandry become more tenuous endeavors. For people living near protected areas, one strategy in the face of uncertain food supply may be to look to other resources, including the plants and animals present in various types of nearby reserves. Managers of the various protected areas will need to be mindful of such increased human pressures, with long-term solutions requiring broad strategies that include implementation of means to help meet basic human demands in addition to the protection of natural resources.

Tanzanian population is growing, increasing by about 9 million (more than 28%) between the census in 2002 and estimates for July 2011 (World Bank, 2011). With growing population comes growing demand, and escalating pressure on natural resources and natural habitat. Conservation increasingly requires planning, actions purposefully aimed towards conserving biological diversity. In Tanzania, this may well require a national strategy that incorporates conservation priorities, on the one hand, and human impacts on the other. Tanzania, as with other countries, cannot conserve everything and still provide for its people. However, with proper planning and effective conservation actions built upon that planning, it may be possible to conserve much to represent the diversity of life in this nation of remarkable biological resources.

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CLIMATE CHANGE: WILDLIFE, WETLANDS AND WATER RESOURCE MANAGEMENT IN TANZANIA

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ABSTRACT
Climate change and direct human impacts are predicted to lead to increasing conflicts for water in Tanzania. This threatens not just wildlife in National Parks and other protected areas; it affects the very survival of entire ecosystems at the scale of whole watersheds. Several Tanzania's National Parks are threatened by these water-related issues. Ecohydrology-based solutions are called for.

Key words: *Climate change, human impacts, wildlife, wetland*

INTRODUCTION
Climate change is happening worldwide (Figure 1). Even the Berkeley group of sceptics is now accepting global warming as their data mimics those of NASA and NOAA; the unresolved issue is to what degree is this change caused by human activities. According to the IPCC projections, by 2100 the atmospheric CO2 levels will be higher than in the past 650,000 years, and the global temperatures will be amongst the highest in the past 740,000 years and this will affect Africa (Boko et al., 2007).

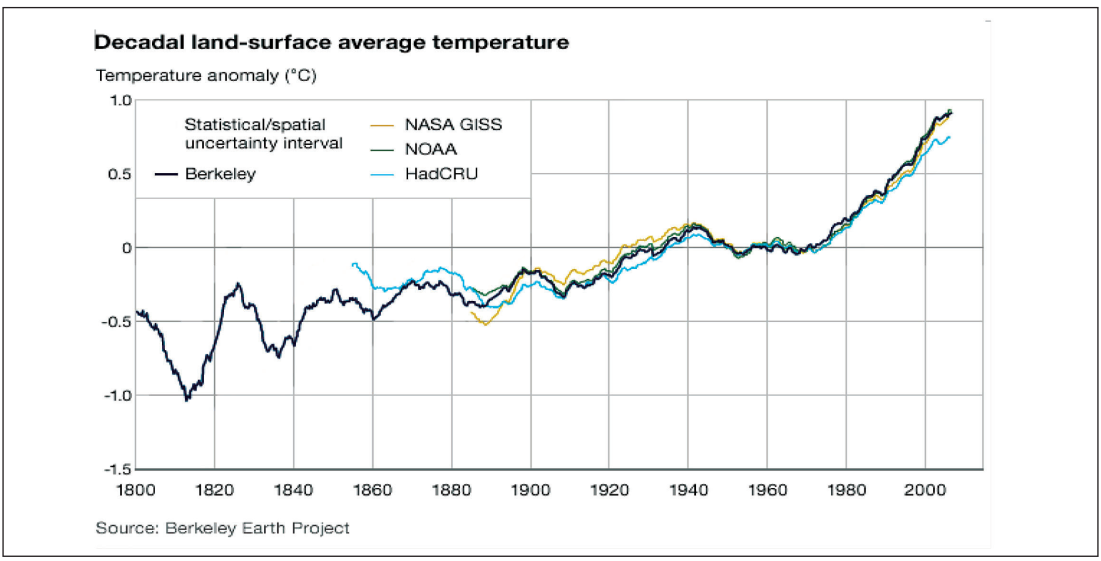

Figure 1. Decadal land-surface average temperature since 1800. Source: Berkeley Earth Project.

Prediction of the future water cycle

What does this climate change bring to Tanzania freshwater and wildlife? It will bring warming and changes in rainfall, evaporation and wind.

Evaporation will increase. Seasonal water bodies will dry faster in the dry season and this will impact wildlife migration. This will negatively impact the Serengeti, Mikumi, Mkomazi and Katavi National Parks, where such seasonal water bodies are important to wildlife. The exception may be wetlands because the total evaporation E (E= free water evaporation + evapotranspiration) is smaller than in open waters because of shading by the vegetation, especially the floating vegetation. Evidence from that comes from the Sudd wetlands in the Sudan where E is reduced by 50% by the vegetation, the Okavongo wetlands in Botswana where E is reduced by 50% to 0.5 cm/day, and the eastern Usangu wetlands in Tanzania where E was also reduced by about 50% by the vegetation that has fully recovered since cattle was removed (Kihwele et al., 2012 and references therein).

The mean rainfall in Tanzania may already be increasing by as much as about 1.5 mm/year for the rainfall over Lake Victoria, 2.28 mm/year for the rainfall at Mbeya, and 2.8 mm/year for the rainfall over the Serengeti (Figure 2). There is however in addition a very large interannual variability that may mask the mean trends.

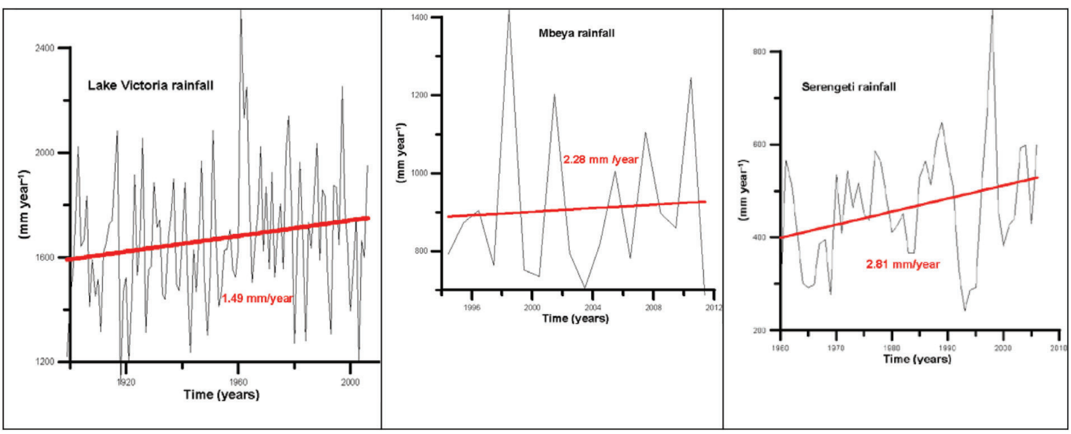

Figure 2. Time-series plot of mean rainfall.

In addition it is expected that inter-annual fluctuations in rainfall in Tanzania will increase with global warming. Evidence for that comes from the study by Wolff et al. (2011) of varve deposits in Lake Chala at the Kenya/Tanzania border. These studies extending 18500 years in the past show that with warming comes more windy years, more rainfall on the average, that dry years will be drier and wet years will be wetter. However, these data do not include the temperature and for prediction purposes it is necessary to correlate Wolff's data with the historical data of the surface temperature of Lake Victoria extending to 1500 years before present (Tierney et al., 2010). With unknown errors in these predictions, this yields the prediction that by 2100 a severe drought now happening every 15 years will happen every 11 years and that mean rainfall will increase by 9%.

More windy, dry years could be beneficial for Lake Tanganyika because it will mean more primary productivity and thus presumably more fish from larger internal waves (Naithani et al., 2007); however, whether this increased wind will be sufficient to overcome the increased water stratification due to warming which is unprecedented since AD500 (Tierney et al., 2010) is unknown. For Lake Victoria, this will probably mean more fish kills from the bottom anoxic layer surfacing from larger internal waves (Kiwango and Wolanski, 2008; Mnaya et al., 2011). For Tanzania's papyrus wetlands it will probably mean more burning, more CO_2 released to the atmosphere and more eutrophication of waters (including Lake Victoria). It is important to remember that the above and below ground biomass of papyrus wetlands at Rubondo Island National Park reaches about 4000-8000 g C/ m^2 , which is very large and comparable to (though smaller) that of mangroves and the peat forests of Kalimantan (Jones and Muthuri, 1997; Mnaya et al., 2007).

Climate change does not come alone

Climate change will not come alone. It will come with a massive growth in the population of humans (Figure 3) and cattle (Tanzania has 12.5 million head of cattle, 6.5 million goats and 3.1 million sheep, which is increasing at a rate of 2.7% per year; MALD (1984); all require water and this will lead to increasing water conflicts with wildlife. Where water and wildlife will be in 2100 will largely depend on where Tanzania decides to be in 2100 depending on political decisions both in Tanzania and in the world, namely (1) whether the world focuses on Gross Domestic Progress (GDP) with climate change increasing (970 ppm CO_2) or the world focuses on Genuine Progress Indicator (GPI; Costanza et al., 2008) with climate change stabilised (350 ppm CO_2), and (2) whether Tanzania focuses on GPI, social and environmental well-being, sustainable human and cattle population or if Tanzania focuses on GDP and consumerism. In the worst scenario, Tanzania could mimic India, i.e. it will become extremely crowded, water resources will be over-taxed, there will be dwindling wildlife, and there will be increasingly bitter conflicts for water between people and wildlife and virtually no respect of minimum environmental flow requirements. According to the latest census released in March 2011 by India's National Tiger Conservation Authority, the current tiger population is estimated at 1706 animals, which is a long way off the 45,000 tigers that roamed India 100 years ago. Will similar pressures reduce Tanzania's elephant population from about 140,000 at present (http://www.tnrf.org/groups/wildlife) to 5300 by 2100?

This coming water crisis is already affecting Tanzania's water, wetlands and wildlife as issues within Tanzania and as transboundary issues (Elisa et al., 2010; Mnaya et al., 2011).

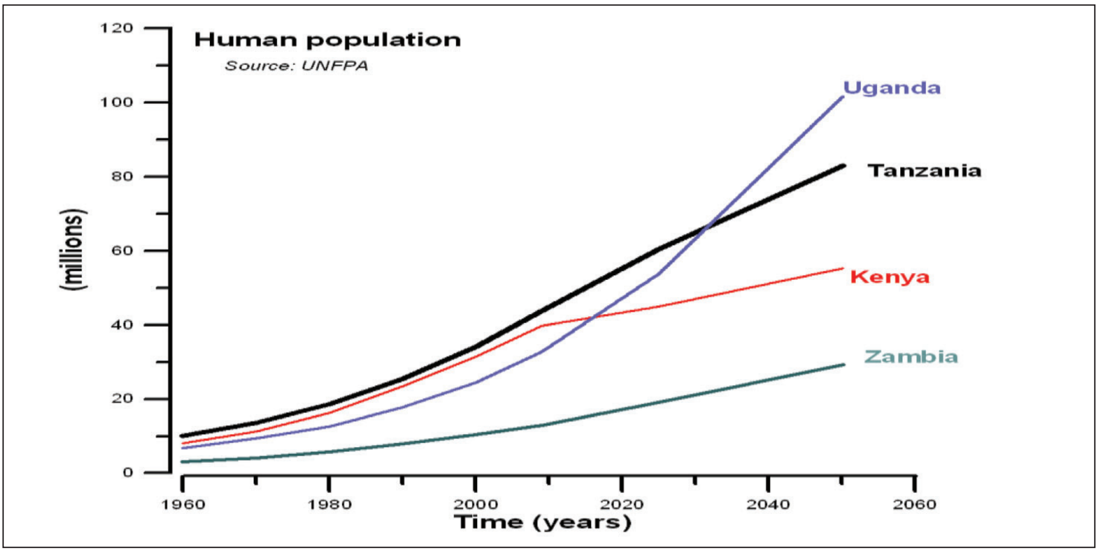

Figure 3. Time-series plot of the population in Uganda, Tanzania, Kenya and Zambia.

An example is the Usangu wetlands where the removal of cattle from the eastern Usangu wetlands has stopped and partially reversed the drying out of the wetlands with increasing flow available for the Great Ruaha River and its use for hydroelectricity production while the western Usangu wetlands from which cattle was not removed is silting at about 12 cm/year (Kihwele et al., 2012). A similar severe problem of siltation from poor farming practices is affecting Lake Manyara National Park, possibly ultimately leading to the degradation of the whole aquatic ecosystem; the evidence is qualitative but strong (e.g. tourist kayak safaris have been cancelled due to increasingly shallower waters (Y. Kiwango, pers. comm.). Similarly the same problem of dams and excessive extraction of water for irrigation without considering mimumum environmental flow requirements is also degrading Katavi National Park where its wetlands (Lakes Katavi and Chada) are now often dry with huge impacts on wildlife; this impact is so severe throughout the watershed that it is even degrading Lake Rukwa and its fisheries (Elisa et al., 2010). Similarly, a major proposed irrigation is threatening the maintenance of minimum environmental flows in the Wami River in Saadani National Park (Elisa et al., 2010). Tanzania wetlands are also stressed from transboundary issues, namely the papyrus wetlands around Lake Victoria suffering from excessive use of water for hydroelectricity from the White Nile River in Uganda, and the Mara River in the Serengeti National Park degrading from deforestation of the Mau forest in Kenya and excessive water extraction in Kenya (Kiwango and Wolanski, 2008; Gereta and Wolanski, 2008; Gereta et al., 2009; Mnaya et al., 2011); this is threatening the very survival of the Serengeti ecosystem as the Mara river appears now set for the 1st time in recorded human history to dry out in the next big drought, which climate change may bring along (Mnaya et al., 2011).

CONCLUSION

With climate change and massive growth of human and cattle population, it seems a fair prediction to expect increasing challenges for water, wetlands and wildlife. There is no experience in human history to what we may face with all these changes and what solutions may become available. To paraphrase Chapman (2011), "Climate change means never going home again". There is a need for wildlife managers to find local solutions by focusing on water quantity and water quality. Solutions require using ecohydrology to find solutions for water, wetlands, humanity and wildlife. Fortunately under the leadership of Dr. Emmanuel Gereta initially and now of Dr. Bakari Mnaya, Tanzania National Parks (TANAPA) has built up its human capacity in ecohydrology and water resources management with several well-trained and enthusiastic MSc graduates, many of them graduating from the European Erasmus Mundus MSc program. They offer the hope that, at least for Tanzania's National Parks, these important water, wetlands and climate change issues will be vigorously addressed by TANAPA.

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A PRELIMINARY SURVEY OF ALIEN INVASIVE PLANT SPECIES IN SERENGETI: A CALL FOR PROMPT PREVENTATIVE ACTION.

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ABSTRACT

Alien invasive plants have the potential to compromise the biodiversity, resilience and function of affected ecosystems. Effective control of alien invasive plants requires fundamental data on their diversity, distribution, abundance and ecological impacts. Prompt investigation makes it possible to understand patterns of colonization, competition and the ecological dynamic of the invader plant. Preliminary reports indicate the presence of several alien invasive plants in Serengeti National Park (SNP) as well as in neighboring villages in the north. However, reliable information to determine the extent and severity of the invasion was lacking and is the impetus for this survey. Ground survey data (road transects and quadrats) are used to examine the distribution of alien plants in SNP and a case study about the control of Opuntia vulgaris in Singita Grumeti Reserves (SGRs) is presented. The survey revealed thirteen alien plant species belonging to ten families. Of all the aliens, Amaranthus hybridus, Opuntia vulgaris, Datura stramonium, and Pistia stratiotes are widespread. These species threaten the biodiversity integrity of the Serengeti ecosystem if no immediate control and monitoring action is implemented. O. vulgaris has already colonized large areas in the west and Ikoma woodlands while Pistia stratiotes invades the Grumeti river. The combined chemical and mechanical control in Singita successfully kills O. vulgaris, however, we would recommend use mechanical approach as immediate action and a further investigation on the future effects of glyphosate on wildlife and soils. To obtain a clearer picture of the invasion we recommend an intensive survey in the whole system to include rivers as well as tourist camps and lodges.

Key words: *Alien invasive plants, Plant invasions, Serengeti National Par*k,

INTRODUCTION

Alien invasive plants can be viewed as the greatest threat to native biodiversity in the world (Blackburn et al., 2004). Invasive alien species were introduced to Africa either intentionally for economic reasons or unintentionally as by-products of intentional introductions (Emerton & Haward 2008). The growth in trade, travel and transport is causing more and thus leading to increased environmental and conservation problems worldwide (Randall 2000). Effective control of these invasions requires fundamental data on the composition, diversity, distribution, and abundance of these species (PWTB 2008), their invasion modes, rates of spread, as well as their potential and known effects (Wittenberg & Cock 2001). Delayed control allows for the rapid establishment of invasive plant species in a particular area from where they quickly become widespread across the landscape (Veldtman et al., 2010). Moreover, delays in monitoring make it difficult to understand the pattern of colonization, performance and ecological dynamic of the invader plant.

Plant invasions have been reported in several parts of Tanzania (URT, 2006) including in formally Protected Areas (PAs) such as the East Usambara Mountains (Darwin initiative Project 2008) and Ugalla Game Reserve (UGR) (TAWIRI 2011). Notable among them was the serious invasion of water hyacinth in Lake Victoria (Bwathondi & Mahika 1994). Several species of AIPs are already widespread within the country including herbs (Opuntis vulgaris, Opuntia imbricate, Datura stramonium, Lantana camara, Argemone mexicana, Acacia mearnsii among others (URT, 2006).

Previous vegetation studies in SNP have been largely focused on plant physiognomy (Anderson & Talbot 1965; Bell 1968), distribution and mapping (McNaughton 1975), plant dynamics (Dempewolf et al. 2007; Anderson 2008; Reed et al. 2009) and human wildlife interactions (Kaltenborn, et al 2003). However there has been an increasing recognition about plant invasions in the Serengeti and Ngorongoro Conservation Area (NCA) (Foxcroft, et al 2006, NCA 2010). Extensive surveys of AIPs have been conducted in the Singita Grumeti Game Reserve (SGGR) immediately adjacent to the north western part of SNP (Mduma et al 2010). In an earlier survey Opuntia was found to be widely distributed within borders of SNP (Nkya 1995). However no comprehensive data regarding the level of plant invasions by various alien plants within SNP. To address this shortfall we used simple inventory and mapping methods in order to establish the presence and level of encroachment by certain alien invasive plants within SNP borders. Information generated from inventory and mapping work can substantially increase the ability of park ecologists and managers to analyze and prioritize invasive plant management needs. Furthermore, an initial spatial quantification of invasion is essential as a baseline for long-term monitoring of invasive alien plants and can be an invaluable resource in the effort to minimize the ability of introduced species to establish and/or spread into unaffected areas of the park. We combine quantitative data on the proportion of alien species in different habitats and encounter rates with AIPs along linear corridors, along which many species are known to spread (PWTB 2008), to construct the first map of the level of alien plant invasion for SNP.

MATERIALS AND METHODS

Study area

The Greater Serengeti ecosystem encompasses a 25,000 km^2 mosaic of open plains, open and dense woodland and riverine habitat in the northwest of Tanzania and southwestern corner of Kenya. At the core of this globally important ecosystem lies the 14,800 km2 SNP which is situated between 330 50^0 to 350 20^0 E and 10 28^0 to 30 17^0 S. The south-eastern part of SNP is open grassland transitioning from vast short grass to long grass plains as one move northwest along the rainfall gradient. The northern sector of SNP, up to the Kenyan border, is largely woodlands whereas the western corridor is composed of a more heterogeneous mix of open and wooded areas. Two important rivers – the Grumeti and Mbalageti - run roughly parallel through the western corridor on their way to Lake Victoria at the park's extreme western edge. The open grasslands of the far southeast typically receive <600mm of rainfall/year, inadequate even to sustain fire in the presence of heavy grazing, whereas the central woodlands receive up to 900mm/year with an annual maximum of 1200mm/year in the extreme western and northwestern corners (Sinclair et al. 2008). In these regions fire is an important component of the ecosystem. Under normal circumstances almost all the rain falls in two seasons, the short rains (November-December) and long rains (March-May). However inter-annual variations are inevitable due to climatic events such as El Nino and the increasing impacts of climate change (Sinclair, per.com in 2010). The southeastern plains are treeless and exhibit a mix of alkaline tolerant rhiszomatous grasses and forbs (Herlocker, 1976). The structure becomes more heterogenous as one move northwest until woodlands abruptly dominate south and east of Seronera in the approximate centre of the park (Sinclair et al. 2008). This area is characterized by a relative diversity of habitats including riverine forests, swamps, kopjes, grasslands and woodlands which allows for a variety of plant species. The woodlands are dominated by Acacia species throughout (with the exception of a small portion of the northwest) but display high small scale heterogeneity in woody cover. Balanites aegyptica and Commiphora species are also widespread and common with other broad leaved species such as Terminalia, Euclea and Croton as sub-dominates (Herlocker, 1976).

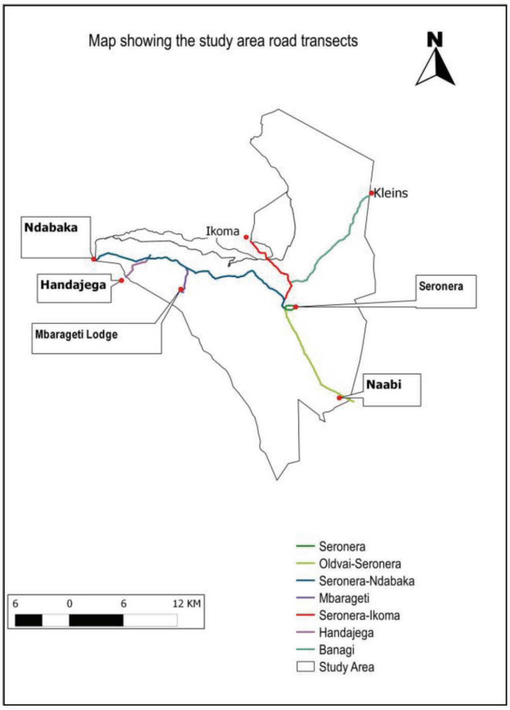
Data Collection

We employed a ground-based approach to collect data on population parameters (i.e. species composition, patchiness, and distribution). These types of data are critical for successful control and management strategies of Invasive plants (PWTB 2008). Once invasive plants were located and identified we used qualitative and quantitative methods to characterize species presence and the extent of invasion. AIP locations and invasion boundaries were determined with the aid of a global positioning system (GPS). The frequency of occurrence of each identified AIP was of primary concern and was determined by measuring the number of quadrants and/or road strips that contain the invasive plant. The invasion pattern of each AIP was described according to PWTB (2008): Single (S); only one plant was encountered, Scattered (Sc); when more than one plants were encountered and spread across sampling area and Patched (P) when a group(s) or patch (es) of the plants are within sample plot.

Many AIPs utilize linear corridors such as roads and railway lines to invade new habitats (PWTB 2008). As such we conducted index surveys along major roads (2m on each side) within SNP (Fig. 1) and quantified both the total number of AIPs present and the rate at which they were encountered. This approach could allow a rapid understanding of the spread of AIPs with reference to park boundaries and other potential points of interest (i.e. roads, bridges, quarry etc.). Road strips were divided into 500m sections and each section characterized as having a presence or absence of each species which allowed an invasion frequency to be determined for each AIP.

Quadrat sampling was undertaken to characterize the extent of invasion of Opuntia vulgaris and Pistia stratiotes after these two alien invasive species were detected in off road vegetation in the Nyasirori, Ndabaka and Ikoma areas of SNP. These three locations were then further sampled. In each sampling site, 100m by 100m quadrants were set at intervals of 100m and the quadrat area covered by the invasive species was estimated visually.

Presence of AIPs along roads and in off-road quadrats was mapped to give an overall visual impression of the current level of invasion within SNP (Fig. 2). The identified species exhibit different colonization strategies with some only occurring in patches or individually scattered in close proximity (ie Opuntia vulgaris, Pistia stratiotes) whereas most others show mixed strategies and also frequently start as isolated single plants (e. g. Amaranthus hybridus, Tegetes minuta, Cassia occidentalis) (Fig. 3). The most widely distributed species is Amaranthus hybridus which appears in all 6 road strip transects, followed by Tegetes minuta and Bidens spilosa which are in all except one of the transects (Fig. 3).



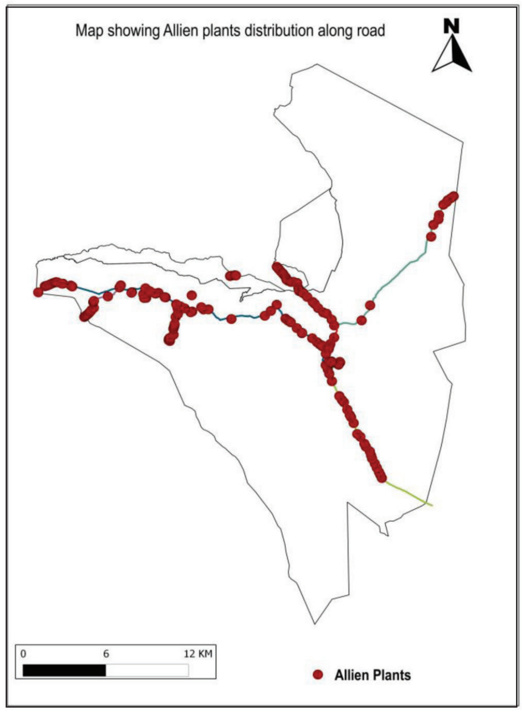


Figure 1: Map of SNP showing the road transects. Figure. 2 Distribution of Alien Plants (Opuntia vulgaris excluded) along selected roads in SNP

RESULTS

Thirteen (13) alien plants belonging to ten families were encountered during road strip and quadrat surveys (Table 1). Lantana camara and Cassia didymobotria were encountered only once each along the Handajega and Seronera-Ikoma transects respectively (Fig. 3). The Seronera-Ndabaka transect showed the highest number of alien invasive plants (9) with Amaranthus hybridus and Cassia occidentalis most common. The Seronera-Ikoma transect had the next most alien invasive species (8) with Amaranthus hybridus and Tegetes minuta well represented (Fig 3). Most transects had several invasive species fairly evenly represented, but the Handajega transect was dominated by Amaranthus hybridus (>75%) as was the Mbalageti transect (>55%) (Fig 3). Argemone mexicana and Pistia stratiotes were not encountered on road transects used in the analysis but the former found along the road to Serengeti Wildlife Research Center (SWRC) at the newly constructed bridge near the junction to Sero 2 campsite (Plate 8) while the latter in a water pools at Hembe area, Birila lodge, Grumeti camp and some pools along Grumeti river. Opuntia vulgaris does not use linear corridors, instead colonizing woodlands or bushlands. Figure 5 shows the degree to which individual transects are affected by alien invasive species, showing the percentage of all 500m sub-divisions where invasive alien species are present for all six transects.

The 50 km Seronera-Ikoma transect is the most comprehensively affected with 69% of sub-divisions containing alien invasive plants and the Mbalageti transect (16km) was next with 65.6% of sub-divisions impacted. The 70km Seronera-Oldvai transect was the least impacted (20.7%) with the Banagi-Kleins transect (90km) also significantly less impacted (27%) than the other 4 (Fig 5).

Table 1: List of Alien plants encountered in the survey

S/N	Species	Family
1	*Opuntia vulgaris Mill.*	Cactaceae
2	*Gomphocarpus kaesneri* L.	Asclepiadaceae
3	*Amaranthus hybridus* L.	Amaranthaceae
4	*Lantana camara* L.	Verbenaceae
5	*Tagetes minuta* L	Compositae(Asteraceae)
6	*Xanthium strumarium* L.	Compositae(Asteraceae)
7	*Ricinus communis* L.	Euphorbiaceae
8	*Datura stramonium* L.	Solanaceae
9	*Cassia didymobotrya* Fresen	Caesalpiniaceae
10	*Cassia occidentalis* L.	Caesalpiniaceae
11	*Bidens pilosa* L.	Compositae(Asteraceae)
12	*Argemone mexicana* L.	Papaveraceae
13	*Pistia stratiotes* L	Nymphaceae

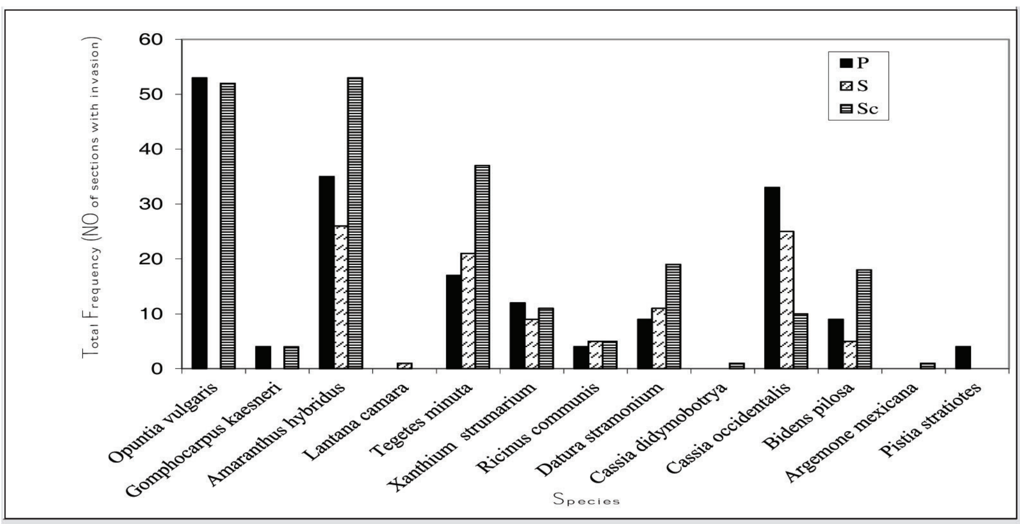


Figure 3: Distribution of alien plants along selected areas in SNP, showing the total number of road sections (N=491) in which each AIP was found to occur. The relative abundance of each type of invasion pattern is also shown (Patchy (P), single (S) and scattered (Sc).

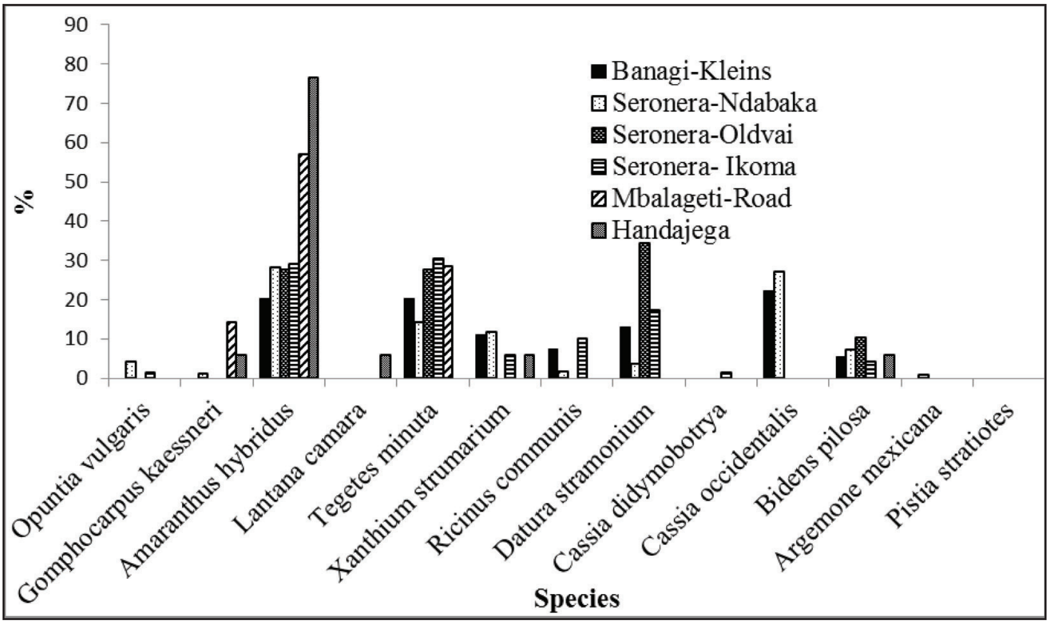


Figure 4: The proportion of each alien invasive plant species found in each of the 6 road strip transects

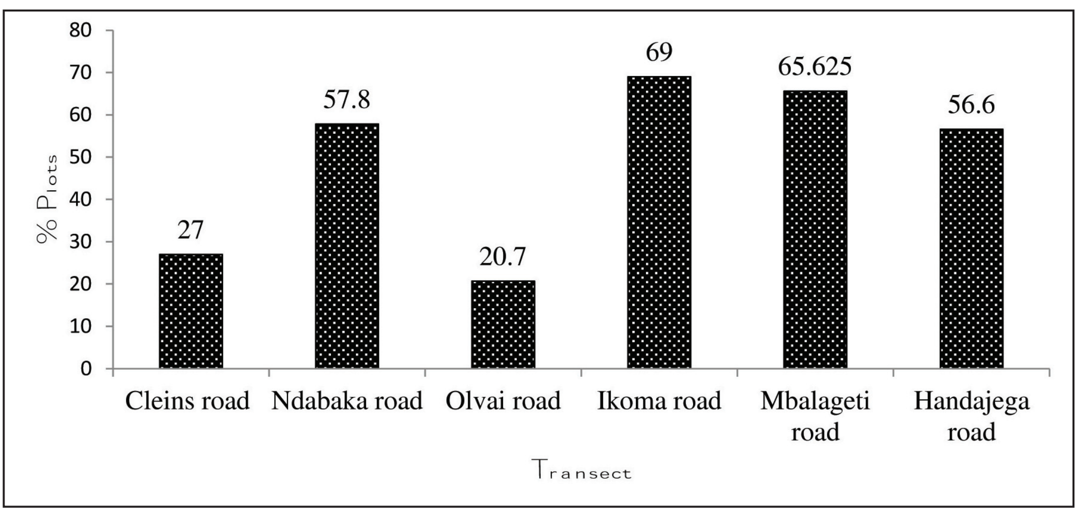


Figure 5: Percentage of 500m sub-divisions with alien invasive plants present across the six road strip transects

The total proportion of surveyed area covered by Opuntia vulgaris accross the Nyasirori, Ndabaka and Ikoma quadrats (45.2 km²) is 11.95% (5.4 km²), with the highest coverage in Nyasirori (Figure 6). Field observations show that Opuntia was highly patced in Ikoma with nearly similar coverage area as in Nyasirori

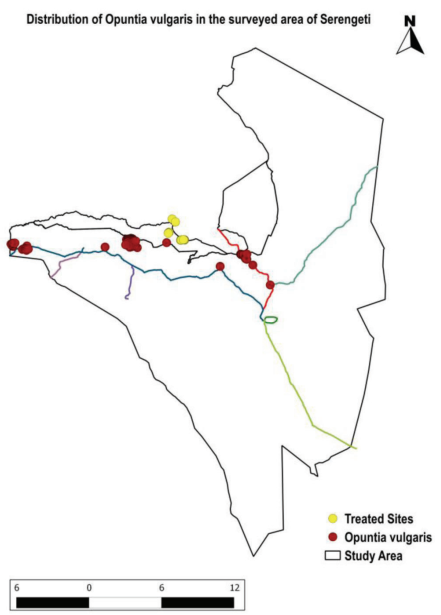


Figure 5: Map of SNP showing the distribution of O. vulgaris

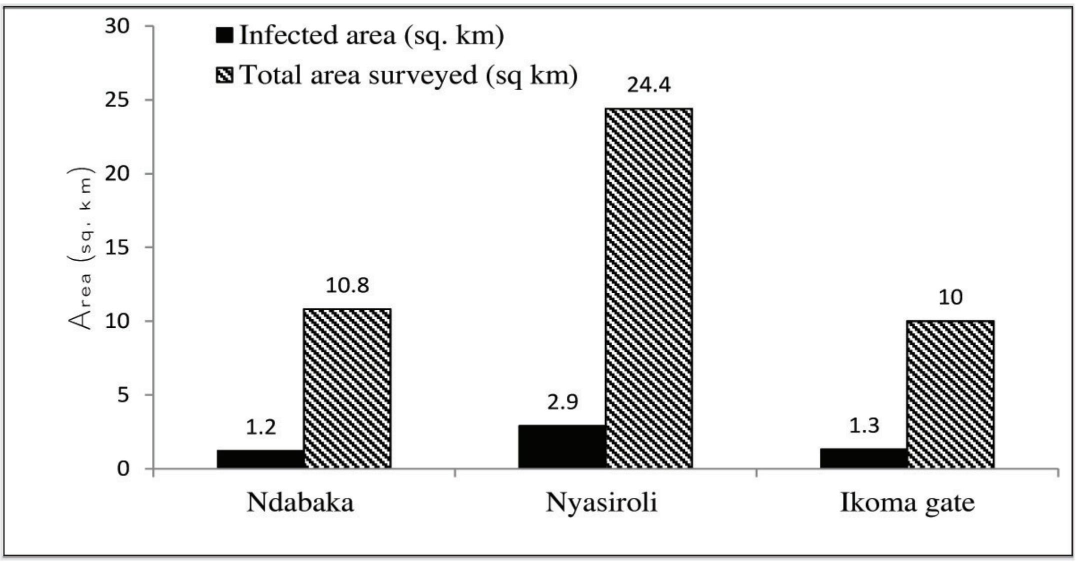


Figure 6: Proportion of surveyed areas occupied by O. vulgaris present in 3 major study sites in Western SNP.

DISCUSSION

Plant inversion in SNP

A diversity of alien invasive plant species are represented within SNP, with 13 species detected during this preliminary survey. The invasion has ramifications for future control, as the diversity of invasive species ensures that no single approach is possible, given the specific invasion cycle of each species (Lipinski & Soll 2003). The invasion cycle by alien plants has three components: Arrival, establishment and spread (Lipinski & Soll 2003, Emerton & Howard 2008). The population growth of an established alien plant in an area starts with a lag phase during which they occur at low densities and their impacts are not noticeable. It is quite possible that many of the alien plants identified in SNP are in their lag phase, as their impacts on the system are still unforeseen.

The duration of the lag phase varies depending on the species and circumstances in an invaded area (Lipinski & Soll 2003, Emerton & Howard 2008). Therefore there is need for reliable information to characterize the nature of invasion (Davies & Sheley 2007) as we cannot assume that an apparently insignificant occurrence of an alien species is safe to ignore. Their rate of spread may rapidly change and may become hard to control. Usually when alien species become established and once the population is at its explosion phase (rapid multiplication and spread across the landscape) the impacts rapidly become apparent (Lipinski & Soll 2003, Emerton & Howard 2008) and hard to contain both logistically and financially. The aforementioned invasion of water hyacinth in Lake Victoria whereby the World Bank spent US$9.3 million to attempt to control and mitigate the invasion (Collins 2000, Thomas et al 2004) is an example of the high cost of allowing an alien invasive species to spread widely. Another good example is the currently existing worldwide struggle by researchers to develop suitable management strategy of a highly invasive weed Parthernium hyserophorus (Shabbir & Adkins 2011).

Expected impacts of each of these species vary according to species and conditions (Limpiski & Soll 2003, Emerton & Howard 2008). Although the overall impact of alien invasive plant species in SNP appears relatively minor at this point, field observation have already revealed the potentially negative influence of O. vulgaris on the composition and abundance of native plants in many of the areas it colonizes. It is observed that O. vulgaris grows densely and forms nearly impenetrable barriers in areas of patchy bushland. These dense stands might hinder the establishment and growth of smaller shrubs and ground flora (See Plates 1-2). Furthermore, it was observed that browsers do not feed on the plant and dense patches could limit grazing and browsing capacity. It is therefore very important to closely monitor these areas now, before the explosion phase of the species is attained. These observations are similar to those published by the Victorian resources online (http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/).

D. stramonium has an allelopathic effect on other species giving it the potential to compete with many pasture species and is thus likely to reduce available fodder for a variety of faunal species if it becomes widespread (http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/). Although the current survey in SNP did not focus on determining the allelopathy behavior of D. stramonium, a sign of growth suppression on other pasture species was observed in the field especially when D. stramonium was in large patches. On the other hand T. minuta is reported to have strong inhibitory activity of the root growth in maize plants (Scrivanti et al in http://www.efn.uncor.edu). Whether there is a similar impact on the root growth of other species, such as those growing within SNP is still a question to be investigated. This underlines the potential hazard in ignoring AIPs within SNP when they are at a seemingly innocuous stage. Since the current survey was largely focused on road transects, only investigating a single off-road invasive species (Opuntia vulgaris (Prickly pear) where it was very noticeable from the road transects, therefore it is possible that invasive plant species that do not use linear corridors to colonize are significantly under-represented. Furthermore, the degree to which species enumerated along road transects have moved away from roads is unknown. These factors indicate that a comprehensive, random sampling strategy be employed throughout the park to estimate the distribution of alien invasive plants into the woodlands and grasslands where they would pose a potential threat to the biodiversity integrity of SNP.

Plate 1: *Opuntia vulgaris* in Ndabaka

Plate 2: *Acacia drepanolobium* woodland being colonized by O. vulgaris in Ndabaka

The distribution and existence of a substantial diversity of alien invasive plant species along roads within SNP is perhaps not surprising because of the abundant traffic entering the park coupled with constant repairs necessary to maintain roadways. Roads are fragmented and disturbed areas which are usually vulnerable to infection by invasive plants which arrive as seeds stuck in the dirt between tire treads; in sand, gravel and rock loads that are brought in as part of the construction process; and in the clothing and luggage of people entering the system from outside (PWTB 2008). Thus, construction and transportation seem to be important avenues for plant invasions in SNP. When alien plants are introduced in an area (either intentionally or unintentionally) their establishment usually depends on some agent(s) of disturbance or where native plants are weakened and stressed (Emerton & Haward 2008). The construction process, whereby existing vegetation is cleared and the earth disturbed for the establishment of widened roads, culverts, bridges etc. thus produces the exact conditions necessary for invasions to take place.

Once established, alien invasive plants reproduce and become increasingly more widespread with time. Their spread occurs when seeds or fragments of live roots and stems are moved from one area to another where they may root and start a new infestation. The transport of these plants can be accomplished in numerous ways with vehicles easily carrying seeds and/or stems from one area to another and natural disturbances like floods transporting seeds or plant fragments downstream. Furthermore many Alien plants like Bidens pilosa, Xanthium stramonium, Datura stramonium and Opuntia vulgaris have special structures that help disperse seeds away from the mother plant (Richardson et al 2000, Davies & Sheley 2007). Animals can also carry seeds either externally or internally, aiding in the spread. This potential method of alien invasive spread is of special importance in migratory systems like the Serengeti whereby large numbers of animals are regularly moving long distances across the landscape.

It is proposed that previous human activity may be the core reason for the existence of Opuntia in SNP (Nkya 1995). Due to lack of efforts to control or eliminate O. vulgaris from these areas, the plant seems to be well established and widespread and has invaded new sites. Field observations in affected areas indicate that this species may be spreading to areas it did not exist. This expansion is probably due to animal and bird movements in the system (Wichmann, et al 2009). In areas where O. vulgaris is well established and forms large stands, the growth of other species appeared to be limited, a indication that this AIP is indeed out-competing native flora (Plate 1).

Case study: Efforts of control of Opuntia vulgaris in Sigita Grumeti Game Reserves

Control efforts using a combined mechanical and chemical approach in SGGRs shows possibilities of minimizing the effect of Opuntia vulgaris invasion. Control efforts were initiated by SGGRs ecology department using an extensively used TOUCHDOWN Forte 500 SL which contains glyphosate as active ingredient, a systematic post-emergence non-selective herbicide which is meant for control of virtually all annual and perennial weeds. TOUCHDOWN is approved by the Tanzania Pesticide Research Institute (TPRI) for use in Tanzania and is reported to be active against grasses, broad leaf weeds and some woody bushes and tree weeds. Several experimental studies emphasize that Glyphosate does not bioaccumulate, biomagnify, or persist in a biologically available form in the environment; its mechanism of action is specific to plants and it is relatively nontoxic to animals (Solomon et al 2009) According to a review of 58 studies testing the impacts of glysophate on organisms, the chemical posed a minimal acute and chronic risk in terrestrial environments for non-target species

(Giesy et al 2000). However, use of Glyphosate has been successful in protected areas elsewhere (Battaglin et al 2008).

However, Glysophate is a contentious chemical. Several other studies other studies have pointed to negative impact on pregnant rats and their fetuses (Daruich et al 2001), in African clawed frogs (Xenopus laevis) (Paganelli et al 2010) and in earthworms and other invertebrates (Hassan et al 1991). Thus a critical consideration of these research outcomes is important successful and sustainable control efforts.

In the current case study, initial efforts involved a series of trial concentrations (Plates 3 & 4) but the 30% concentration was found to be successful in weakening the stems which then dried out within a few days in SGGRs (Plate 6). However, follow up observations of seemingly dead plants show that O. vulgaris can regenerate from these plants in the next rainy season (Plate 6) thus suggesting the necessity of continued monitoring and follow up action in these areas. Coupling the chemical with other mechanical approaches (cutting and burning), O. vulgaris is more successfully destroyed and there was clear evidence of regeneration of indigenous species in some of these areas (Pers. obser.). Though the current work did not have any targeted experimental test for determining the effect of glyphosate on wildlife, there were no any observed impacts resulting from the ingestion of this chemical by large mammals in the treated areas, this being inline with the report by Victoria Resource Online (http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/), there are no large animals that feed on the O. vulgaris, possibly deterred by the conspicuous spines. Moreover, during field surveys, small mammals (esp. Rat sp) were visually observed inhabiting some of the sprayed areas after the eradication of O. vulgaris. However, the long term impact of glyphosate on these and other small animals and microorganisms is still poorly understood.

Plate 3: *O. vulgaris* treated with 8% glysophate in October 2010 at Ridge Road area SGGR (Photo in Feb 2011)

Plate 4: *Opuntia vulgari*s treated with 15% glyphosate in November 2010 at Ridge Road area SGGR.

Plate 5: *O. vulgaris* treated with 30% glyphosate

Plate 6: Regeneration of O. vulgaris at a formally destroyed patch

CONCLUSION AND RECOMMENDATIONS

Alien Invasive plant species are present within the borders of Serengeti National Park, with 13 different species identified during this preliminary survey. Surveys were predominantly conducted along roads so a bias toward finding AIPs that colonize along linear corridors is possible. Presently the level of invasion, although widespread (especially for certain species such as Datura stramonium and Amaranthus hybridus), does not appear overwhelming, however a central feature of AIPs is their ability to spread extremely rapidly once a foothold has been gained. As such we recommend close monitoring of all AIPs identified during this survey as well as a wider, more comprehensive survey to include all SNP roads, rivers, tourist lodges, campsites as well as interior tracts important pathways for colonization. This work needs to be initiated soon in order to gain a robust appreciation for the true impact that these potentially destructive AIPs are having and therefore prioritize management action.

Opuntia vulgaris does appear to be widespread in various parts of the Western SNP and seems to be out-competing native species where it is abundant. A case study from Singita Grumeti Reserves (SGR) whereby a combination of chemical and mechanical removal methods were utilized to counter-act the invasion of O. vulgaris shows promise although follow up observation and further remedial action may be necessary as this AIP species appears to be resilient. Furthermore, the long term effects of glysophate on wildlife need to be carefully monitored in order to avoid unintended consequences in the Park. Thus, mechanical approaches should be used first and a very limited and carefully controlled application of the chemical only where absolutely needed.

Creation of general awareness on the type of invasive plants and their ways of inversion to managers, researchers, rangers and other stakeholders is necessary. The prevention of new invasive plant infestations could be improved by developing more effective tools for limiting dispersal of invasive plants. Identifying the major vectors that disperse an invasive plant and then developing strategies to reduce the dispersal effectiveness of those vectors is critical to limiting new infestations.

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THE INVASION POTENTIAL OF ALIEN PLANT SPECIES WITH REFERENCE TO CLIMATE CHANGE IN NGORONGORO CONSERVATION AREA

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ABSTRACT

The introduction and subsequent invasions of alien plants is one of the mega threats facing Ngorongoro Conservation Area (NCA); a multiple land use area with Outstanding Universal Values (AUVs) where natural resources conservation, pastoralism, and tourism are managed in a harmonious manner. NCA is inscribed on the World Heritage List as a mixed natural and cultural site, which spans a vast landmass stretching from the Serengeti National Park (SNP) in the north-west of Tanzania to the eastern arm of the Great Rift Valley. Invasive alien plants persist at low numbers for many years, slowly and often dangerously increasing before they suddenly explode. The unpredictability situation and time lag between when an alien plant is introduced to a stage of becoming invasive coupled with the increasing climate change, poses the challenge on the prediction of how NCA habitats respond to those aliens. Alien species that have become invasive elsewhere have caused significant management problems as they become extremely disruptive, damaging, interfering with natural processes and threatening the survival of naturally evolved plant assemblages and individual indigenous species. To effectively manage alien plant species and mitigate their long-term impacts in NCA, a long term assessment of their abundance and spread trends and the associated climate change in particular rainfall patterns was initiated with the aim of assessing and recommending the possible control measures.

Due to the fact that rainfall in NCA is seasonally and spatially variable with complex vegetation types, the area offers spectacular and beautiful topographic features, which are rich in biodiversity. Alien plants discussed in the current study were identified based on available literature and from field surveys. Determination of the species' potential and risk of invasiveness followed procedures applied in other areas as described in the surveyed literature. Recorded alien plant species in NCA have increased from 50 in 2002 to 143 in 2010, an increase that shows an inverse relationship with annual rainfall. Basing on pathways for introduction and the plant's intrinsic ability to become invasive, 15 species are identified to have high potential of becoming invasive while 8 species are likely to become invasive if given time and exposed to enabling conditions. Priority setting for eradicating and/or controlling the nine alien plant species with high risk of invasions should be undertaken. So long as climate change is closely related to the increasing abundance and the subsequent invasions of alien plants, prevention of introductions should be the first and most cost-effective option over eradication and control. We recommended that awareness creation on social, economical and ecological negative impacts of alien plants and the subsequent consequences of invasions on ecosystems should be made so as to maintain the area's World Heritage Site status.

Key words: *Alien species, Invasiveness, Climate change, NCA*

INRODUCTION

Ngorongoro Conservation Area is a high value biodiversity area, which is a pioneering experiment in multiple land use where pastoralism, conservation of biodiversity and tourism co-exist in a managed harmony. However, this kind of management philosophy renders NCA vulnerable to constant constraints and stress emanating from various factors including the introduction of alien plants. The introduction of ornamental plants and importation of construction materials both for buildings and road maintenance from outside NCA are the major source of alien plant species observed in the area today. In that regard, centres for social services including schools, health centres, camping sites, lodges, and staff quarters represent important foci for the spread of alien plant species in the area.

A species that occurs outside its known historical natural range, no matter how long ago it has been introduced is referred to as an alien. Most alien species can only survive in their adopted new areas if they are cared for. However, others manage to flourish in their new environments, reproduce and maintain their populations without human assistance and these are termed as naturalized species. If a naturalized species is able to spread over considerable distances into new undisturbed natural areas and replace indigenous species it is regarded as invasive alien species.

Historically, alien species were considered to spread from other continents to Africa through colonialism and exploration. Today, their spread is through among others tourism and business travel. Further, changes in climate and land use are rendering some habitats more susceptible to biological invasions through facilitation. The concern on the introductions and spread of alien plants has however, increased recently as reflected in the 1993 Convention on Biological Diversity (CBD) and in other national and international policies.

Recent studies indicate that Tanzania is one of the countries in African Continent that face invasions of alien plants; a problem which is addressed in the Wildlife Policy of Tanzania (WPT) of 1998 (URT, 1998); revised in 2007. In NCA, light infestations of alien plants are already evident (NCAA, 2011).

The ability to predict the invasiveness of alien plants and on how the habitats respond to those plants are the major challenges that face ecosystems conservation activities, particularly with the current climate change (Kareiva, 1996). Invasive alien plants persist at low numbers for many years, slowly and often insidiously increasing before they suddenly explode (NCAA, 2011). Groves (1991) points out that of the entire introduced alien plants worldwide only about 10% become established and 10% of the established become invasive. Hiebert and Stubbendieck (1993) indicate that in many areas, the number of alien plants that have had no detrimental effects on natural ecosystems is usually far greater than the numbers that become invasive. However, the few invasive species portray significant management problems by being extremely disruptive, damaging, interfering with natural processes and threatening the survival of naturally evolved plant assemblages and individual indigenous species.

Furthermore, few that become invasive have a substantial time lag between initial introduction and subsequent population growth (Williamson, 1996). Thus, the risk emanating from invasive alien plants in NCA is apparent as those invasions would become more severe with time as populations mature and spread, if action is not taken now. The major factors contributing to alien plants' invasions include history of invasiveness, intrinsic life history traits such as persistence, reproduction, and dispersal attributes and suitable climate or environmental conditions in the new site (Reichard and Hamilton 1997).

To effectively manage alien plant species and mitigate their long-term impacts on NCA ecosystem functions, a long term assessment of their increase with regard to numbers and the associated climate change in particular rainfall patterns and intensity was initiated in 1998 in order to assess their spread trends and recommend possible control measures. This paper focuses on the history and current situation with regard to alien plant species and their management in NCA with a general aim of identifying, determine trends and prioritize existing alien plants aiming at recommending measures that will manage effectively those species in the NCA. Specifically,

METHODOLOGY

Study Area

The study was carried out in Ngorongoro Conservation Area in northern Tanzania (Figure 1.) covering an area of 8,292 km^2; a protected area that was established in 1959 to reconcile the conservation of natural resources, interests of resident pastoralists and the promotion of tourism (NCAA, 2006).

Rainfall in NCA is seasonally and spatially variable. Average rainfall between 1964 and 2009 at NCA headquarters representing the midlands was 845 mm/year ranging from 503 mm to 1,152 mm (Sampling Error = 29). The years 1965, 1967, 1983, 1989, 1993, 1994, 1995, 1997, 1998 and 2007 whose annual rainfall deviated highly from the mean were excluded from the analysis (NCAA, Annual Reports). The average annual rainfall for the eastern slopes of the crater highlands is 1,200 mm/year while that on plains is only 400 mm/year (NEMP, 1992).

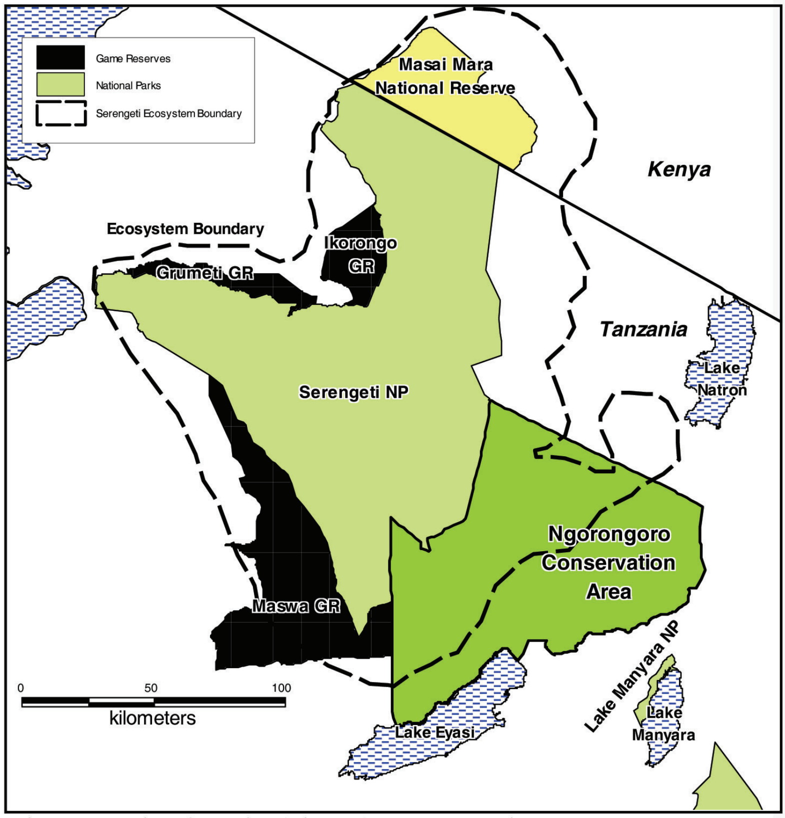

Figure 1: Location of NCA in relation to the Great Serengeti Ecosystem

The vegetation of NCA is complex consisting of montane forest and tall grasslands in the highlands, woodlands in midlands and short grassland on the plains. It is this physico-ecological diversity, which produces both spatial and temporal grazing, water and mineral resources that result in the extensive migration of both wildlife and domestic animals (Lane and Moorehead, 1994). The area offers spectacular and beautiful topographic features, which are rich in biodiversity. Apart from wealth biological resources and topographical beauty of which NCA boasts, the area also provides some of the most important archaeological and palaentological sites in the world. The value of NCA is magnified by presence of about 65,000 pastoralists who live alongside wildlife practising transhumance mode of livestock production and keeping about 130,000 cattle and 160,000 goats and sheep (NCAA, 2007).

Declared as a World Heritage Site in 1979 based on natural values and UNESCO having recognized its cultural values in 2010, NCA remains one of the world wonders of the 21st century. The area was classified as a Biosphere Reserve by UNESCO in 1981 and it is a Tanzania’s tourist treasure, which attracted nearly half of the tourists who visited the country in 2001 (BOT, MNRT, NBS, IMMIGRATION DEPT. and ZCT, 2004).

Data Collection

Alien plants in NCA were identified based on available literature and from field surveys. All the lodges and staff quarters' premises, camping sites, ranger posts, schools, and health and trade centre located within the NCA were visited. Surveys were also carried out on water bodies located in the Ngorongoro crater, along the descending and ascending crater roads and in some settlements just outside NCA including Karatu and Mbulumbulu areas (Figure 2).

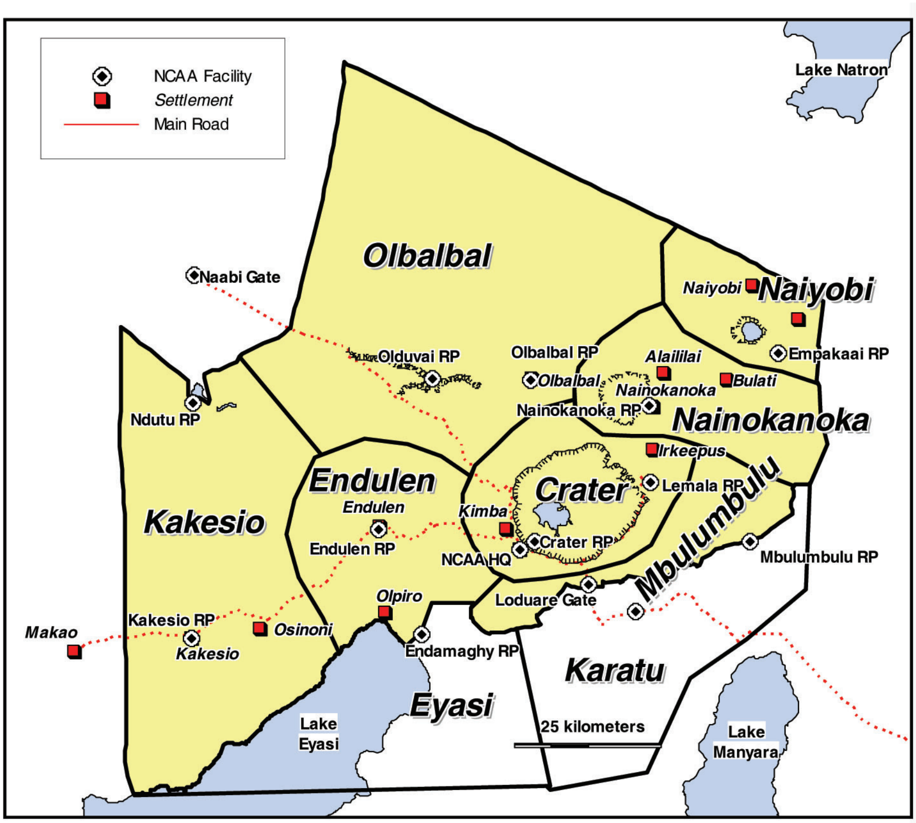

Figure 2: Sampling sites

Data Analysis

A search using appropriate websites to determine the behaviour of the alien species elsewhere was applied. From a list of alien species that was obtained in 2007, a ranking system to classify the plants according to the species level of impact and its inherent ability to become invasive as described by Richardson et al. (2000) was done. The data set included species in all stages of invasion from those currently introduced to those already showing signs of invasion.

RESULTS

Trend in the Number of Alien Plants in NCA

In 1998, Datura stramonium, Argemone mexicana and Nicandra phaseoloides were noted growing sporadically along the roads in the Ngorongoro Crater floor. The end of the dry season in October and the heavy rains that followed in November and December of the same year 1999 caused the species to spread from the roads into the nearby vegetation and into some of the wetland areas. In 1999 most of the roadsides in Ngorongoro Crater were invaded by D. Stramonium covering approximately 35km2 of the grasslands (Mattay and Lotter, 2005). In 2000, the first control programme began whereby D. stramonium, A. mexicana, A. ochroleus, and Xanthium strumarium were uprooted or cut at base.

The first survey of alien plant species that was conducted in 2002 identified 50 species from within and near to the NCA (Foxcroft, 2003; Lotter and Foxcroft, 2003; Lotter, 2004). Five years later in 2007, 101 species were identified accounting for 100% increase from that of 2002 (Runyoro, et. al., 2008). Alien plant species that were identified in 2007 belonged to 43 families; the three dominant being Fabaceae, which accounted for 11%, Solanaceae (9%) and Myrtaceae (6%) (Appendix I). The survey that was undertaken in 2010 identified 141 alien plant species accounting for 40% increase from the number that was recorded in 2007 (Clarke et. al.;2011). While the families increased from 43 in 2007 to 49 in 2010, Fabaceae, which accounted for 9% of all the identified families continued to dominate, followed by Asteraceae (7%), then Aracea, which accounted for 5% (Appendix 1). The families that were not recorded in 2007 but appeared on the list in 2010 are Crassulaceae, Brassicaceae, Salicaceae, Hydrangacea, Poaceae and Commellinaceae. The alien plants risk assessment that was undertaken in 2007 found that 60% of all the identified species were in the introduction phase, 22% were naturalized and 17% were categorized as invasive. The remaining one percent; Caesalpinia decapetala that was recorded growing mainly along the boundary between NCA and the agricultural communities was categorized as a transformer species. Results indicate that the increasing trend in the number of alien plants recorded in NCA over the period of study was inversely related to decreasing annual rainfall (Figure 3).

Invasion Potential of Alien Plant Species in NCA

Initial establishment, spread and subsequent distribution of alien species in NCA is mostly facilitated by humans through the introduction of ornamental and fruit plants, fencing, planting trees for shade and wind breaks. Bringing plants for ornamental purposes in NCA ranked the highest source of alien species introduction accounting for 54% of all the plants that were recorded, followed by fruits (16%), wind break and shade (8%), medicinal (6%) and those introduced for agricultural purposes accounted for (6%) as well. The remaining 10% were unintentionally introduced by animals, birds, vehicles, wind, flowing water and in construction materials. Based on introduction pathways and the plant's intrinsic ability to become invasive as described by Pheloung et. al., (1999), 15 species recorded in NCA, which have demonstrated to have explosive characteristics elsewhere worldwide are considered to have high potential of becoming invasive. These are Acacia mearnsii, Azolla filiculoides, Caesalpinia decapetala, Datura stramonium, Lantana camara, Leucaena leucocephala, Lonicera japonica. Others are Melia azederach, Tithonia diversifolia, Opuntia inermis, Opuntia vulgaris, Parkinsonia acuelata, Psidia guajava, Senna didymobotrya and Senna spectabilis. Eight species, which are likely to become invasive given time and enabling conditions, are Agave americana, Agave sisalana, Argemone mexicana, Caesalpinia pelcherima, Canna indica, Duranta erecta, Epiprenum pinnatum and Nerium oleander.

Alien Plant Species with High Risk of Invasions

Out of the 23 alien species with the potential and those likely to become invasive, Caesalpinia decapetala; an alien plant species which is planted along the boundary between NCA and the agricultural communities on the south and south-eastern part of the conservation area poses a very high risk of invasion into the NCA. Other plant species, which are already localized in different parts of the NCA with high risk of invasions, are Acacia mearnsii, Azolla filiculoides, Datura stramonium, Lantana camara, Leucaena leucocephala, Lonicera japonica, Melia azadrach and Parkinsonia acuelata.

DISCUSION

Alien plants are unfavourable in conservation areas not simply because they are exotics but because they are potential threats to natural ecosystems. Some of such plant species modify natural and semi-natural habitats causing profound effects on the composition of both fauna and flora of the invaded environment. When most of the alien species become invasive, they replace a diverse system, introduce a new life form to the habitat, change the nutrient status of the soil and they alter the water and fire regimes. Others in particular those which are unpalatable to herbivores may rapidly colonize habitats and eventually cause rangelands degradation.

The relatively high densities and great diverse of alien plants recorded on the western part of the Ngorongoro crater which is comparatively dry as it is situated in the rain shadow than the eastern side which receives higher annual average rainfall indicates that climate is one of the most important factors that favours the establishment of alien plants spatially. The long dry spells followed by heavy rains have shown to favour the proliferation of alien plants probably because the dormant seeds already brought in the area are stimulated to germinate easily by such weather changes. The situation of temporal variations in annual rainfall and the subsequent increasing abundance in alien species in NCA may they demonstrates that climate change rather than methods of introductions facilitates alien plants' invasions.

Literature indicates that besides Euchhonia crassipes Water hyacinth, there is relatively modest research, monitoring and publication of results of invasive alien plants in Tanzania and thus rendering their control and management difficult. The current surveys have revealed that the existence of alien invasive plants in NCA has not reached a stage which is considered uncontrollable. Only 16% of all the recorded species have the potential to become invasive. Thus, a prioritisation for eradication followed by the control measures for those which are not possible to eliminate should be undertaken. The species with high risk of invasions including Acacia mearnsii, Azolla filiculoides, Datura stramonium, Lantana camara, Leucaena leucocephala, Lonicera japonica, Melia azadrach and Parkinsonia acuelata should be given high priority. These should be followed by those identified to have the potential of becoming invasive which are Tithonia diversifolia, Opuntia inermis, O. vulgaris, Psidia guajava, Senna didymobotrya, S. spectabilis, Agave americana, A. sisalana, Argemone mexicana, Caesalpinia pulcherima, Canna indica, Duranta erecta, Epiprenum pinnatum and Nerium oleander.

In this study, Caesalpinia decapetala is identified as a transformer alien in NCA because it is a perennial plant that does not require disturbance to flourish. This plant species was recorded on the margins of the boundary with the nearby agricultural communities and therefore poses a potential threat to the biodiversity of the natural undisturbed areas of the NCA. Transformer plants generally cause a considerable alteration to the indigenous biodiversity and therefore efforts to eradicate this plant species should also be given precedence.

CONCLUSION AND RECOMMENDATIONS

Invasive alien plants tend to persist at low numbers for many years, slowly and often dangerously increasing and eventually their populations literally exploding. Control of potential invasive plants should therefore occur before the numbers blow up. The aim of control measures is to reduce the density and abundance of an invasive organism to keep it below economic threshold because the impacts of non-containment are often severe and the cost to clear plants once have become invasive increases exponentially. However, where feasible, prevention of introductions should be the first and most cost-effective option. When prevention has failed, or was not in place at the time of introduction of an invasive plant, eradication is the preferred course of action in response to early detection of potential invasive species in order to determine whether eradication of the species is practicable.

Habitat disturbance resulting from climate change is believed to be one of the major factors favouring alien plant's introductions and the overall invasion processes. Prevention of bare sites caused by such factors as fires, floods, storms and landslides vegetation removal by animals and humans is important to reducing the colonization rate of invasive plant species. With that regard, awareness creation on the social, economical and ecological negative impacts of alien plants and the subsequent consequences of invasion by those species on ecosystems should be made. Eradication or control of prioritized transformer and those species with potential to become invasive in NCA to acceptable levels should be given priority. Apart from researching on the pathways for introductions of alien species, bringing in NCA the known and potentially invasive alien species should be prevented.

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IMPACT OF WILDLIFE MANAGEMENT AREAS ON LIVELIHOOD AND BIODIVERSITY CONSERVATION: A CASE STUDY OF IKOMA-NATTA (IKONA)

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ABSTRACT

Wildlife Management Area (WMA) is a new community-based protected area category in Tanzania initiated in 2003 as means to ensuring local communities adjacent to protected areas benefit from rich wildlife resources endowed in their areas and at the same time conserve wildlife corridors and dispersal areas. The study assessed the impact of Ikoma-Natta (IKONA) WMA on conservation and livelihood took place between 2010 and 2011 and involved two villages, Robanda and Nattambiso. Data were collected through literature reviews, questionnaire surveys, interviews, and physical observations. Sixty households, village and IKONA leaders and District officials participated in the evaluation exercise. Data were analyzed using Statistical Package for Social Science (SPSS) and qualitative data analysis techniques what is it?. The results from this study indicate that between 2007 and 2010 each of the five villages forming the WMA collected TZS 41,500,407 an average of TZS 10 million per annum. In other words each household realized TZS 2,000 per annum. In addition, other perceived benefits were employment, access to water and maintenance of wildlife corridors. The WMA challenges observed were lack of transparency in the use of funds and low involvement of local communities in the day to day running of the WMA. In order for the WMA to achieve the twin goal of livelihood improvement and wildlife conservation, investments in capacity building and law enforcement and effective mass participation; creation of income generating activities; enhancement of transparency and accountability in use of WMA funds; and improvement of infrastructure need to be addressed.

Key words: *Wildlife Management Area, Protected Area, Serengeti, Conservation, Livelihood*

INTRODUCTION

The need for a new category of protected areas in Tanzania, the Wildlife Management Areas (WMAs) arose from the fact that government had little control of what is going on in Game Controlled Areas (GCAs), and yet some of the GCAs are ecologically important (Yanda et al., 2001; URT, 2001; Kessy et al., 2004). The situation led to fewer individuals and people from outside especially the investors in the hunting blocks to gain more influence and benefits in the GCAs. As a result local people felt that they were excluded both from accessing benefits, and the management of the resources which are within their locality (URT, 2001). The scenario prompted the need for a new wildlife management system which would ensure that local people benefit, and take part in the management. WMA in Tanzania is geared towards promoting better management of the protected areas, sustainable use of wildlife resources, devolution of wildlife management and user rights to local communities and sharing of benefits derived from wildlife uses and resources (URT, 1998). However, studies still reports deficiencies of WMAs in realizing people's livelihood, resource governance and its sustainability (Kideghesho et al. 2007).

Ikoma-Natta (IKONA) Wildlife Management Area (WMA) was established in 2005 and acquired an authorized status in 2006. IKONA is of high conservation value due to its strategic position. It is also known as JUHIWAIKO (Jumuia ya Hifadhi ya Wanyama Pori Ikoma – Natta) is surrounded by Serengeti National Park and Ikorongo and Grumeti Game Reserves. However, there are growing concerns about the long-term viability of the ecosystem due to escalating land use conflicts, loss of land, complaints on benefits gained by the local people, an attempt of Robanda village to withdraw from the WMA, and leadership problems in the WMA which bring the local people into increasing resource use conflicts. Therefore, this paper seeks to systematically assess its (WMA) effectiveness, and provide suggestions that may enhance WMA sustainability in management of the Serengeti ecosystem.

MATERIALS AND METHODS

The Study Area

The IKONA WMA is surrounded by Serengeti National Park to the East and Southeast; Grumeti Game Reserve to the South and Southwest; Ikorongo Game Reserve to the North and privately owned Grumeti Reserves to the West (see Fig. 1). IKONA WMA covers an area of 480.1 km², and is jointly managed by villages of Robanda, Park Nyigoti, Nyichoka, Makundusi, and Nattambiso (IKONA Resource Management Zone Plan, 2005). The altitude ranges between 1144m and 1380 meters above sea level. The temperature shows a relatively constant mean monthly maximum (Mligo and Lyaruu, 2008) and mean annual rainfall stands at about 700 mm. The soils are silt clay mainly, non-cracking sandy clay and sandy loam soils. However, stony or sandy loams over clayish subsoil are found on sloping areas. Some reddish loamy sands with a thin dark humus layer on hilltops and the ridges of escarpment can be found in some places. Vegetation in the area is woody, sparsely consisting of shrubs, grasses and herbs. (IKONA Resource Management Zone Plan, 2005). The large mammals found in the IKONA WMA are mainly those associated with savannah systems, but also with a combination of species found between Miombo woodland and acacia savannah. The most common large mammals in the area are elephants, lions, buffaloes, giraffe, hartebeest, waterbuck, wildebeest, warthog, leopard, topi and zebra. There is also a variety of bird species associated with open grasslands.

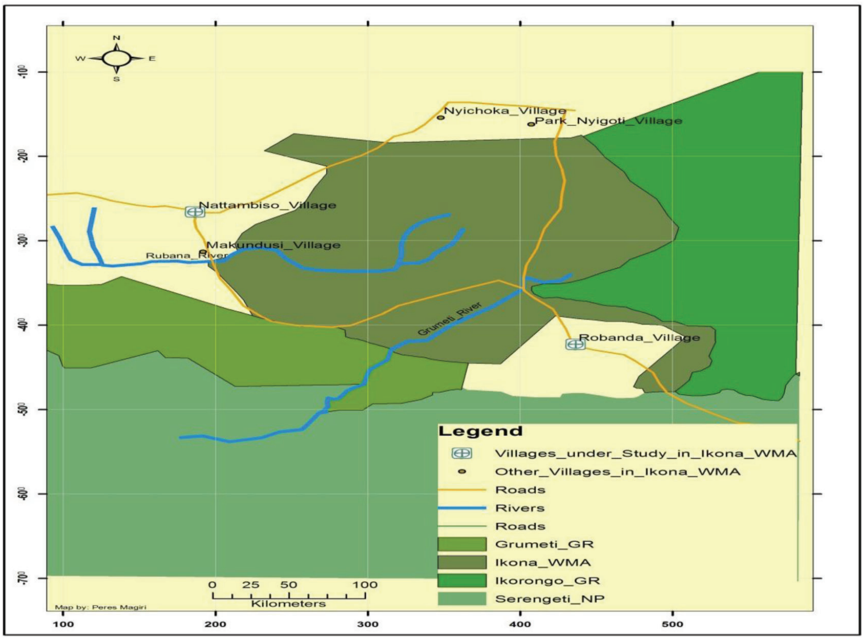

Figure 1: Location of the Study Area

Study Area Selection Criteria

IKONA WMA was selected over other WMAs in the country because of three reasons: first, it is among the first 16 pilot WMAs in Tanzania; second, the abundance and diversity of wildlife species; and third, IKONA WMA is a strategic wildlife corridor . The two study villages Robanda and Nattambiso were selected because of richness of wildlife, presence of several business investors, and the potential resource use conflicts.

MATERIAL AND METHOD

A combination of methods and techniques were employed for both secondary and primary data collected. These methods included literature reviews, household surveys and key informants interviews. For secondary data collection: publications relevant to the study were accessed from libraries, search engines, government offices, Non-Governmental Organisations (NGOs), and IKONA WMA itself. These included books, policies and regulations, strategic action plans, journal papers, and conceptual material on all the ideas, debates and issues relevant to the subject matter. Collection of primary data involved the use of self-administered questionnaires to the households which were a unit of enquiry. The questionnaire which had both open and closed questions contained several aspects such as livelihood and conservation, strengths and weaknesses of the WMA, and challenges of IKONA WMA. Before questionnaire administration, a two days training of research assistants on survey tools and the questionnaires pre-testing were carried out.

Households were sampled from the household village register list using a systematic random sampling method. The sample size was 60 households from 2 villages. It is suggested that a minimum of 30 items to be included in a sample when statistical analysis will be adopted (Saunders et al., 2000; Kothari, 2004). Systematic random sampling was chosen over other sampling methods because of higher degree of representativeness of the sample, sample is spread evenly over the population, less tedious, more time saving when using large population, and saves costs (Krishnaswami, 2003; Adam and Kamuzora, 2008). Personal interviews with key informants were conducted using a checklist guide. Checklist guide had themes that included establishment, livelihoods, conservation, strengths, weaknesses, challenges and sustainability of WMAs. The interviewees were purposely selected including two village chairpersons, two village executive officers (VEO), one IKONA secretary, and one District Game Officer (DGO). Site visits were conducted in the study villages to assess the implemented projects, resources within the area, human activities and its impact to environment and natural resources.

Data analysis

The collected data from questionnaire was thoroughly examined, variables coded and then imported into Statistical Package for Social Science (SPSS) version 12.0 for both open-ended and closed-ended questions. The SPSS software was used because of its quality in data analysis, and also the researchers had an expertise on application of the software. After completion of data entry in the SPSS, data were cleaned before carrying out an analysis. Cross tabulations, frequencies and percentages were obtained.

The collected data from interviews were mainly qualitative in nature. As pointed out by several social science researchers, qualitative data analysis has no one right way to proceed with analysis (Hesse-Biber and Leavy, 2004). Thus before interview data were analysed, the responses were categorized into various classes which are called categorical variables (Kombo and Tromp, 2006). By using impressionist summary technique, the researchers recorded the key issues of the interview, summarized key findings from frequent responses, and provided explanation, interpretation and conclusion of the findings.

RESULTS AND DISCUSSION

This section is organised into several sub-sections namely the socio-economic characteristics of respondents, the contribution of IKONA WMA on community livelihoods and biodiversity conservation, the strengths and weaknesses of the WMA and the challenges of IKONA WMA.

Socio-economic Characteristics of Respondents

The total number of households involved in the survey was sixty. According to field data about 65% of the household respondents were males. At specific village level, again males were dominant (See Table 1a).

Table 1a: Demographic Characteristics of the Respondents

Village	Sex (%) n=30		Age (%) n=30			
	Male	Female	18-28	29-38	39-48	≥49
Robanda	66.7	33.3	13.3	53.3	13.3	20.0
Nattambiso	63.3	36.7	23.3	26.7	23.3	26.7
Average	65.0	35.0	18.3	40.0	18.3	23.4

On age categories, most of the respondents (>50%) were of the age between 18-38 years indicating that most of the population are youth. This is a healthy condition as these are economically active group and they can effectively participate in sustainable wildlife conservation efforts and building their future livelihoods. For example, youths can be recruited as village game scouts, and/or tour guides and as security guards in WMA investments e.g. hotels/lodges or campsites. On the other hand, the broad base pyramid (majority being youths) implies that the population structure in these two villages is stable and can actively be involved in conservation efforts for a long time.

As for education about 93% and 83% of Robanda and Nattambiso respondents had primary education, respectively (See Table 1b). Thus, on average 88% of the respondents in the study area had primary education (seven years of schooling). This implies that the majority have not attained secondary education suggesting high level of illiteracy. According to Kaswamila & Songorwa (2009) the level of education particularly secondary education and above is an important factor in coping with poverty and particularly in coping with risks and uncertainties related to livelihood strategies. A certain standard of education can better equip a person to structure their conservation enterprises to be sure that the family has enough to meet their requirements for cash, food and shelter (Kaswamila & Songorwa, 2009). To the contrary Manyong et al., (2006) argues that years of schooling above four years are satisfactory enough to warrant a candidate read and write, which is essential attribute for adoption of conservation technologies. The data also indicates that the main economic activities in selected villages are agriculture and livestock keeping.

Table 1b: Education and economic activities

Village	Education (%) n=30						Economic activities (%) n=30					
	Primary		Secondary		Above		Agriculture		Livestock		Hunting	
	yes	No	yes	No	yes	no	yes	no	Yes	no	yes	no
Robanda	93.3	6.7	6.7	93.3	0	100	86.7	12.3	93.3	6.7	3.3	96.7
Natta	83.3	16.7	6.7	93.3	0	100	96.3	3.7	93.7	6.3	6.7	93.3
Average	88.3	11.7	6.7	93.3	0	100	91.5	8.5	93.5	6.5	5	95

Contribution of IKONA WMA on Community Livelihoods

Local communities were asked to assess IKONA WMA contribution on livelihood strategies. The assessed aspects were in terms of income, employment, accessibility or availability to land water, forest products, non-forest products, wilderness and infrastructure. Answers were restricted to Yes or No. Results show that IKONA WMA contributed in different ways mainly through cash income, employment, access to forest and non-forest products (See Table 2).

In Robanda village the WMA contribution on local people's benefits in order of importance were access to non-forest products, wilderness and employment.

However, they cited land scarcity and poor infrastructure as costs inflicted as a result of establishing WMA. About 72% (104 km^2) of the total village has been set aside as WMA. In Nattambiso the contribution was mainly use of non-forest products, employment and income. Loss of land and poor infrastructure were also mentioned as WMA costs. On the loss of land, one could argue that the benefits accrued from WMA have already been compensated by the benefits from WMA. Overall, in order of most important benefits accessed by local people were the use of non-forest products (92%), employment (73.3%), enjoyment of and/or access to wilderness (68.3%) and income (60%).

Currently nine tourist companies operating within the WMA have employed 23 local people in several positions such as security guards, hoteliers, cleaners, and employment within WMA as village game scouts. Tourist companies currently operating in the area

include Grumeti Reserve, Task Safari, Thomson, Rough Truck, Zara International Safari, Acacia Safari, Tanzania Adventure, Moivara, and Nyishegere. As for income, between 2007 and 2010 the WMA realised about TZS 207,502,407 (IKONA 2009 annual report), an equivalent of TZS 42 million/village or TZS 16,800 per household. Village cash income has been used for public welfare projects in the villages such as construction of schools, clinics and water facilities. The WMA receives revenue from tourist companies that have invested in the villages.The average income realized per household looks small when compared with costs incurred by villagers by virtue of surviving with wildlife.
A study conducted by Kaswamila et al., (2007) show that crop damage to households was on average, 0.08 ton/annum equivalents to two months household loss of food and reduced household cash income by 1.3%. Furthermore, other scholars assert that wildlife-induced costs to benefits received by local communities are high (Songorwa, 1999; Emarton and Mfunda, 1999; Kideghesho and Mtoni, 2008). This is not healthy for WMA sustainability, and attainment of people's livelihoods and wildlife conservation. Robanda village provide a good example of such dissatisfaction as on 3rd August 2011 planned to make a public demonstration demanding the withdraw from IKONA WMA (Nipashe Newspaper of 3rd August, 2011).

Contribution of IKONA WMA on Biodiversity Conservation

IKONA WMA has contributed in enhancing conservation of wildlife resources. (See Table 3). Conservation initiatives have been carried through zoning scheme, tourists' activities, environmental conservation education and law enforcement as detailed hereunder.

In the two study areas the contributions of WMA on conservation initiatives were through tourist activities, environmental education, law enforcement and zoning scheme. Robanda village is currently the leading village in Serengeti District with a high number of tourism activities and/or investments both within the WMA and outside the WMA. On the other hand, Nattambiso is among the fast growing villages in terms of increasing number of population as it is home for most Grumeti Reserve workers and diverse business enterprises including tourism related enterprises. Furthermore, the two villages have the potential to initiate different types of tourism ventures. The potential tourist activities include game drives and viewing, walking safaris, bird watching, photographing and hunting. The challenge to WMA management and village leaders is to ensure proper use of revenues generated from tourism related enterprises so as to enhance biodiversity conservation in the WMA and improve communities' livelihood.

Table 2: WMA benefits to the Community

Accessed benefits	Villages (%)				Average (%)	
	Robanda (%) n=30		Nattambiso (%) n=30			
	Yes	No	Yes	no	Yes	No
Income	43.3	52.7	76.7	23.3	60	40
Employment	63.3	36.7	83.3	16.7	73.3	26.7
Land	6.7	93.3	26.7	73.3	16.7	83.3
Water	60.6	39.4	53.3	46.7	56.9	43.1
Forest products	59.7	40.3	50	50	54.8	45.2
Non-forest products	93.3	6.7	90.6	9.7	91.9	8.1
Wilderness (hunting quota)	83.3	16.7	53.3	46.6	68.3	31.7
Infrastructure (roads)	6.7	93.3	6.7	93.3	6.7	93.3

Source: Field Data, 2011

Table 3: Conservation Measures in the WMA

Measures	Villages (%)				Average (%)	
	Robanda (%) n=30		Nattambiso (%) n=30			
	Yes	No	Yes	no	Yes	no
Zoning scheme	53.3	46.7	63.3	36.7	58.3	41.7
Tourist activities	66.7	33.3	76.7	23.3	71.7	28.3
Environmental educ.	63.3	36.7	50	50	56.7	43.3
Law enforcement	56.7	43.3	66.7	33.3	61.7	38.3

The recognition of environmental education as a contributor to biodiversity conservation in the area can be linked to environmental conservation education efforts that has been going on in the district (including the study area) through various agencies such as TANAPA, Frankfurt Zoological Society (FZS) and Grumeti Reserve. These agencies have been implementing environmental education in villages and/or schools. On law enforcement, the recruitment of VGS in villages and frequent anti-poaching patrols has to a greater extent strengthened and/or reduced anti-conservation activities (poaching, deforestation, uncontrolled fires etc) within the WMA leading to the enhancement of biodiversity conservation.

Table 4: Strengths of IKONA WMA

Strengths	Villages (%)				Average (%)	
	Robanda (%) n=30		Nattambiso (%) n=30			
	Yes	no	Yes	no	yes	no
Village representation	70	30	66.7	33.3	68.4	31.6
Partnership	73.3	26.7	56.7	43.3	65	35
Staff recruitment	56.7	43.3	26.7	73.3	61.7	38.3
Sharing of income	33.3	66.7	73.3	26.7	53.3	46.7

Natural resource management zoning (Zoning Scheme) can be argued to have assisted in ensuring sustainable use of natural resources within the WMA. Currently there are two main zones for tourist hunting (376.1 km²) and photographic safaris (104 km²) zones. In the photographic safari zone a total of 8 investors are currently operating while in the tourist hunting zone the Grumeti Reserve is the sole operator.

Strengths of IKONA WMA

Several strengths of IKONA WMA were identified and these include village representation, partnership with stakeholders, staff recruitment, and sharing of income (See Table 4).

The major strengths of the WMA identified in both villages were partnership with WMA stakeholders, democratic representation of communities, employment to communities and sharing of income accrued from WMA related activities (See Fig.2). At specific village level Robanda communities had the opinion that they are increasingly loosing income after joining the WMA when compared with the situation before joining the conservation initiatives. This situation could be explained by the fact that before the initiative the village used to collect income from tourist companies located in their village. Currently WMA revenues are collected by WMA management and shared by all five villages forming the WMA. In other words, Robanda which owns most of the tourism investments in the area feel they are unfairly treated. Similar views have also expressed by Minjingu village in the Jumuia ya Hifadhi Burunge (JUHIBU) WMA (Kaswamila, 2012). Within JUHIBU the village has the largest number of investors compared to the rest and previously they were collecting revenues from these investors. The WMA guidelines of 2002 require villages forming WMAs to share revenues equally.

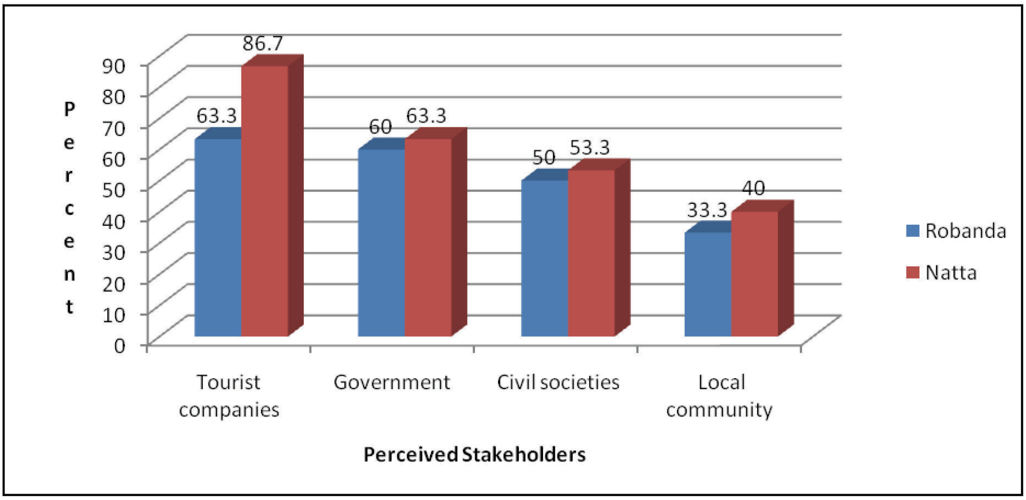

Figure 2: Perception of WMA stakeholders

Equal sharing of revenues seems to be controversial and therefore should be critically relooked for the sustainability of WMAs in the country. In Nattambiso communities had the view that they were getting few employment opportunities. This can be attributed by the fact that the village unlike Robanda has relatively fewer tourist investors and/or tourism potential investment areas.

Partnership with other conservation stakeholders

According to Trauger et al., (1995) a partnership is a voluntary collaboration of individuals, organisations, or both to achieve common goals on a specific project within a definite time. In the context of this study WMA partners identified in Robanda and Nattambiso include tourist private companies, Government, civil societies, and the local community. The WMA is currently working closely with the Serengeti District Council through the District Natural Resources Advisory Board (DNRAB) through collaborative meetings and directives while tourist companies in the area have been the main source of revenues for running conservation activities within the WMA and socio-economic development projects such as construction of water dams, renovation of schools and dispensaries.

The tourist companies currently working in the area include Grumeti Reserves, Tusk Safari, Thomson Safari, Rough Truck, Zara International Safari, Acacia Safari, Tanzania Adventure, Moivara, and Sengo Safari. The former has a substantial influence in the WMA and the district at large as it plays as a major financier (patrols, training, provision of vehicles, infrastructure development etc.) and has gone to an extent of influencing some decisions in the WMA. For example, resident hunting has been halted since 2006 after the company had entered an agreement with the Serengeti District Council (SDC).

The company in turn compensates SDC an amount of TZS 200 million per annum an equivalent of about TZS 4 million/village. This amount is equivalent to TZS 1,300 per household. This amount seems insignificant taking into account the fact that these communities have been denied access to protein and they continue to suffer from human-wildlife conflicts such crop/livestock depredation, loss of property/life and transmission of zoonotic diseases. Trauger et al., (1995) they further argue that partnership require meaningful, participative relationships among two or more partners. The best partnerships are among individuals (not necessarily organisations) where each contributes a combination of time, talent and treasury.

Village representation

Presentations of communities in different WMA organs were seen by most respondents as strength.

According to IKONA WMA constitution each village forming the WMA is represented by five village representatives in the Authorised Association (AA). These representatives get elected by the village assembly, the highest decision making organ in village administrative set-up. The village assembly constitutes all village members aged 18 years and above. During the period of study representation of females in the governing body (AA) were only 20% indicating a gender bias towards men. To achieve sustainability of WMAs inclusion of more women within the WMA structure is of paramount importance.

Employment

Employments offered to communities by the tourist companies and/or WMA were seen as one of the WMA strengths. During the period of study about 23 people were employed by the WMA in different capacities, the majority being recruited as VGS. As for tourist companies, the number could not be established.

However, the majority were employed in the low cadre jobs (non-professional jobs) such as security guards and cleaners.

Table 5: Weaknesses of IKONA WMA

Weaknesses	Villages (%)				Average (%)	
	Robanda (%) n=30		Nattambiso (%) n=30			
	Yes	No	yes	no	yes	no
Lack of transparency	70	30	63.3	36.7	66.7	33.3
Poor community participation	73.3	26.7	53.3	46.7	63.3	36.7
Lack of recognition	60	40	60	40	60	40
Lack of qualified staff	63.3	36.7	63.3	36.7	63.3	36.7

Sharing of income

Communities' perceived income sharing as strength in that income generated by the WMA is shared equally among WMA villages. The sharing of income has several implications to communities and/or individual households. First, the village share has led to implementation and/or completion of socio-economic projects such as schools, health centres and water facilities (dams). Second, local communities have been relieved from frequent contributions of development levy, which at times has led to forfeiture of property for defaulters. Third, the incomes have been very instrumental in conservation efforts such as paying allowances to VGS and WMA staff, preparation of WMA general management plans and/or Resource Zone Management Plan and other WMA overhead costs.

Weaknesses of IKONA WMA

Weaknesses and/or challenges of IKONA WMA are presented in Table 5 below. The weaknesses include lack of transparency in the use WMA revenues, poor community participation in major decision making, lack of recognition, and lack of qualified staff.

Community participation and transparency

Community participation is an active process by which beneficiaries/clients groups influence the direction and expectation of a development project, with a view to enhancing their well-being in terms of income, personal growth, self reliance or other values they cherish (www.wds-worldbank.org). This can be said to occur only when people act in concert to advise, decide or act on issues which can be best solved through such joint action – empowerment, building beneficiary capacity, project effectiveness and project efficiency (ibid.). During household interviews the majority had the opinion that their involvement in major WMA development decisions has been poor and feedback to communities has also been poor. This scenario has led to lack of transparency in the use of funds generated by the initiative. They further argued that feedback and reports on income and expenditure were seldom obtained. And if available there was no room to discuss the reports in detail. The misuse of funds has recently taken a new turn. For example, WMA payments have to be endorsed by the District Executive Director's office and the government has recently directed auditing of the WMA accounts to establish if there is misappropriation of funds.

Qualified staff

The need to have well trained staff in the management of WMA activities is necessary if the WMAs are to leap forward. IKONA WMA is still weak in this area as currently there is only two members/staff with wildlife management skills (DGO, Pers. Com.). Efforts should be made to train people in different areas such as book-keeping, business enterprises, patrols, eco-tourism, biodiversity inventory, monitoring etc. IKONA WMA annual reports (2009) indicate that the WMA has not recruited an accountant and/or wildlife and tourism officers due to financial constraints. To date WMA has recruited 23 staff including a management secretary, an office secretary, a driver and VGS. It is important for WMAs with sufficient funds such as IKONA to give high priority in recruiting staff in areas such as accounting and tourism. These areas are likely to accelerate the growth of these initiatives.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The major findings from this study have shown that the local people in IKONA WMA have realised some conservation benefits. Twenty three local people accrued jobs from the WMA and/or investors, villagers have accessed water and non-forest products and have gained income of about Tshs 10 million for each village since 2007. Public development projects are mainly implemented using WMA funds. However, there was lack of direct
benefits attained at individual or household level to offset costs incurred by conserving wildlife. Conservation initiatives in the WMA have been boosted by zoning scheme, tourists' activities, law enforcement and patrols conducted by VGS. Furthermore, the high number of investors instead in zoned areas threatens the resource use within the WMA and the ecosystem sustainability. IKONA WMA is also severely weakened by lack of transparency in its functioning, poor infrastructure to support tourism industry, and loss of land has been bitter pills for local people in the study villages. The study has further shown lack of quality accounting system and qualified staff.

Recommendations

- In order to attain efficiency and effective performance of IKONA WMA, the following recommendations need to be implemented:-

- For effective management and protection of resources in the WMA, it is recommended that IKONA WMA should ensure rural households/individuals access to direct benefits.

- In an attempt to address the issues of accessing direct benefits/income in the WMA, it is recommended to establish a Savings and Credits Cooperative Society (SACCOS). The cooperative society should provide loans with soft conditions like allocating small interests on loans and effective loaning system in the five villages forming IKONA WMA.

- It is recommended to build capacity of WMA administrative and operational oversight capacity. This will help among others to increase the collection of revenue due to IKONA WMA, and enhancing natural resource management and protection. By managing revenue collection, the WMA can gain more income than what is received from Wildlife Division through CITES, the government agency supervising tourist hunting and photographic safaris in the WMAs.

- Roads to support management and a vibrant tourism development in the IKONA WMA are very poor. It is recommended to improve existing roads and construct new roads that will eventually increase the flow of visitors to the WMA.

- It is recommended that before any infrastructure is improved or initiated and before any permits are issued for commercial development, a thorough Environment and Social Impact Assessment (ESIA) be performed.

- The law enforcement in IKONA WMA is undertaken by Village Game Scouts (VGS). However, the study has shown that VGS work under difficult conditions including lack of working tools/gears, low payments, and minimally trained. Since VGS work is very essential if the wildlife and natural resources of the WMAs are to thrive therefore, it is recommended to increase VGS incentives and/or packages.

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THE SOCIO-CULTURAL AND ENVIRONMENTAL GAINS AND LOSS OF TOURISM TO THE LIVELIHOOD OF INDIGENOUS SOCIETIES LIVING ALONG THE TOURIST ROAD FROM MAKUYUNI TO NGORONGORO GATE IN ARUSHA, TANZANIA

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ABSTRACT
The study assessed social-cultural and environmental impacts of tourism on livelihood of indigenous societies along 130 km tourist road from Makuyuni to Ngorongoro gate in Arusha, Tanzania. Questionnaires structured around the Likert scale, focused group discussion, interviews and documentation review methods were used to investigate community perceptions towards tourism impacts. Qualitative and quantitative information from 133 respondents were gathered, measured, and interpreted. All the respondents agreed that tourism activities were the main cause of socio-cultural and environmental changes in the area. About 70% were more concerned that tourism activities were causing cultural distortion, commoditization of culture, shortage of land, health problems, increase cost of living, and overutilization of natural resources. However, 62% of respondents' perceived tourism as a tool bringing people of different cultures together, provides direct contact between the two parties, understanding between nations, and leads to employment, financial gain for individuals and environmental conservation. The study concludes that despite all the negative and positive impacts of tourism on the area, it is not yet clear whether the benefits outweigh the costs in perspectives of the local people. A reason for this vagueness is that 52% of respondents favoured tourism while 48% condemned it as a dirty industry.

Keywords: *Tourism, Environment, Livelihood, Social Cultural heritage, Ngorongoro*

INTRODUCTION
Tourism is one of the three main international commercial exchange sectors along with petrol and motorized vehicles. Many national economies are now heavily reliant on tourism. Integrated in the leisure world, it has become a mass phenomenon, and at the same times a social necessity. The term tourism is sometimes used pejoratively, implying a shallow interest in the societies and natural wonders that the tourist visits. The tourist is usually interested (among other things) in the destination's climate,

culture and nature. Long (2007) explains that the wealthy people have always travelled to distant parts of the world, not incidentally for some other purpose, but as an end in itself: to see great buildings or other works of art; to learn new languages; or to taste new cuisines, to study the new way of life of other people and to enjoy the scenery of geographical features and land formation.

The rapid growth and impact of the industry has placed at the centre of international discussions on sustainable development. From an economic perspective, tourism is widely endorsed for creating economic growth and development (WTO, 2005). The sector makes a considerable contribution to the global economy through exports, Gross Domestic Product (GDP), employment and investment. In 2004, travel and tourism generated 10.4% of world GDP, 9.4% of global capital investments and 12.2% of universal exports of goods and services (WTTC, 2004). These all places tourism in the top five export categories, preceded only by exports of chemicals, automotive products and fuels (WTO, 2005). In specific countries, tourism is one of the largest sources of foreign exchange in countries such as Costa Rica, Belize and Guatemala (Acharya, 2001).

As one of the world's largest industry, tourism has the capacity to improve the material life of communities that have lost traditional industries as trade barriers have fallen. The impact of tourism on developing countries is a critical sustainability issue. Proponents note that in recent years, tourism's economic contribution in many developing countries has exceeded that of traditional economic activities such as agriculture and mineral extraction (UN, 1999). From an economic perspective, tourism is widely endorsed for creating economic growth and development (WTO, 2002). For instance in Maldives, tourism provides 17% of the GDP, over 25% of government revenue and around 60% of the foreign exchange (Chauhan and Saeed, 1998). There is no doubt that tourism can increase job opportunities, improve standards of living and ensure community development.

However, tourism can also have severe negative impacts on a community, outweighing any economic and cultural benefits. Tourism, viewed from another perspective, is a factor of acculturation which affects attitudes, alters popular beliefs, changes mentalities and spreads new concepts relating to work, money, and human relationship. It has also been observed by UNESCO (2004) that tourism can destroy the ties that bind people to their traditions, faith, religion and aesthetics. A restaurant, bars, discos and other means of entertainments cause disturbing public behaviour, drunkenness, vandalism, crime, indecency, etc. Local youth in many cases emulate the visitor's behaviour and social conflicts arise. The large number of persons travelling to tourism destinations often exceeds the carrying capacity, and can affect environment in various ways (McLaren, 2003). Overconsumption of natural resources such as freshwater, energy, land and marine resources can lead to resource depletion and degradation. The overall outcomes will lead to resource conflicts between locals and the industry (Gossling, 2003)

Tanzania is one of the few countries gifted with an array of tourism resources - from bio-cultural diversity to a wealth of histories and antiquities. The country is endowed with various natural resources that form a root of tourist attractions; almost a third of the land area is allocated to natural parks and game control areas. In reality, some of the attractions have contributed largely to the growth of Tourism in the nation including protected area, diverse in cultural attributes, historical sites and old monuments. The prehistoric cities, which once glorified and also signify religious sanctity to date, are still the magnets to the tourists. As a share of total exports, tourism earnings increased from 15% in the 1980s to over 50% in the 2000s, becoming the second largest foreign exchange earner after agriculture. Tourism earnings as a share of GDP increased significantly, from about 1% in the 1986-92 period and over 6% in the 1993-98 to 12% in 2000-2004 period; one of the highest in sub-Saharan African countries (Kweka and Ngowi, 2007). In 2001 the sector contributes 4.5% (TZS 1, 698.5billion) of GDP (WTTC, 2004) and it contributed 377,000 jobs directly in 2011 which are equal to 3.7% of total employment (WTTC, 2010). Tanzanian tourism polices passes in various levels that have threatened the integrity of ecosystem, and today, many politicians, scientists, activists and local communities are struggling to balance the need for economic growth with the preservation of natural resources in respect with traditions. Thus understanding the complex impact of tourism to socio-cultural and environment in a local space can play decisive role in management of tourism sector. This study therefore, went along the ways to investigate the socio-cultural and environmental gains and loss of tourism to the livelihood of indigenous societies living along the tourist road from Makuyuni to Ngorongoro gate in Arusha, Tanzania,

METHODOLOGY

The tourist main road from Makuyuni to Ngorongoro gate is located in Arusha region, Monduli and Karatu District, which covers area of 136 km². It was officially upgraded in 2002, making it one of the best and newest tourist roads in Tanzania. It brings travelers to Manyara National Park, Karatu town, Ngorongoro Conservation Area and Serengeti National Park. Along the road there are indigenous residences of Maasai and Iraqw, as well as other small non-native communities pulled by economic and social activities. Site selection was based on criteria that permit greater understanding of the effects of tourism within communities experiencing different levels and types of tourism within their surroundings. Study sought communities of similar size, economic (farming and animal husbandry) history, and ethnicity (native settlements) to enhance opportunities for meaningful understanding and comparisons.

The study employed both Qualitative and Quantitative techniques. Qualitative techniques were employed to determine the attitudes and perceptions of the sample group. On the other side, quantitative techniques were employed for the purpose of quantifying the economic gains and losses of tourism in the study area. The sample (N=133) consists of tourism officials (N=12) in local levels who creates, manage and implement tourism policies, tourism practitioners (business personnel) (N=30), native people who live in the study area (N=68) and tourists who visited a study area during the study period (N=23). The representative respondents were obtained through purposive, systematic, convenience and quota sampling. Six villages within the study area were selected, the criteria for selecting these villages was proximity to the main road. Primary data were collected through structured questionnaire of the variables, face-to-face interviews, participatory rural appraisal, and observation and focused group discussion. Secondary data were obtained through the use of related documentary review. The schedule allowed the researcher to have an opportunity to observe community life before, during, and after the high tourist season. The findings of study were analyzed by the use of frequencies, percentage, crosstab and the use of Likert Scale

The validity of the questionnaires allowed bases on the changes that the mock-respondents gave. Once the questions were edited and some additional information on the possible gathered background was done, the mock-questionnaires were again given to another set of respondents who again test the validity of the questionnaire. The validity of this study mostly focuses on the decisions generated by the researcher and respondents in order to ensure that the information that was gathered is as accurate and specific; this undoubtedly helped with the formulation of the findings and through the conclusions.

RESULTS

Table 1 presents a breakdown of mean scores of each variable by respondent groups (location, gender, education, age and duration of living). Based on the mean scores of each variable, the results appear to suggest that overall, all respondents involved in this study survey had high levels of awareness of impacts of tourism despite their differences in terms of the localities, gender, occupation, education, age and duration of living in the area. A closer look at the results reveals that even within the group categories with very small numbers of respondents, the lowest mean was still only 3.81 and the highest was 4.41.

Generation of income was observed as the impacts of tourism with mean of 4.4, followed by mean of 4.2 in the statement that tourism encourages employment. The respondents also reported that tourism encourage cross-cultural activities, air pollution in form of smoke and suspended particulate matters from increased number of vehicles and from construction of tourist facilities, and destruct ecological sensitive areas by mean of 4.1 each. Tourism was also seen as the tool for overconsumption of natural resources and destruction of wildlife habitats (with mean of 4.0). Again, the statement tourism promotes culture of the locals (mean of 3.9) was followed and lastly is tourism leads to changes of agricultural goods and services by mean of 3.8.

Promotion of social cultural activities in the area (72.6% of the total respondents) agreed tourism positively contributed in their cultural activities. The cultural attributes such as clothing, dancing, food mannerism, customs and taboos have been a key factor

in tourism attraction that made it to be known internationally. Tourism activities also have an important role in creating friendship between the tourist and the local people which accounted for 68.1% (Table 2). Most of the people have created friends from other places due to meeting with tourist, and others have supported financial and moral supports from tourists. Another social benefit is employment (65.2%). As observed, most of indigenous are employed as tour guide, waiters and waitresses, gift shops along the high way, porters, drivers, managers and similar type of employment which is generated from enhanced tourism activities. Currently, it provides 214,697,000 jobs worldwide, representing one in every 12.3 jobs worldwide or 8.1% of total employment (WTTC, 2004).
Socially, tourism was credited for its potential impact on employment; income redistribution and poverty alleviation. Tourism provide market for the locally produced goods such as arts and crafts that are found in the curio shops, this accounted for 59.3% of the total respondents and was another direct benefit the indigenous people earn after employment. Locally produced goods got market in tourism facilities such as hotels, lodges, entertainment centers, and other accommodation and recreational areas. Improvements of Social Services counts for 57% is another remarkable benefits that the indigenous societies enjoying, most of the schools has been improved and most of the tourists do help in providing reading materials such as books in schools within area. The good example is Endalah Secondary School in Karatu District in which the Tourist once visited the school and they agree to help out the school.

It's clear that most of the local people and an ecologist from Manyara National Park agreed that due to the presences of tourism the natural resources were well preserved in the area and this counted 78.5% of the total respondents. Despite the fact that there are multiple reasons/aims/objectives for establishment national parks, the respondent said there were conservation and preservation of national parks because of presence of tourism. 68.1% of respondents agreed that with activity of tourism in the area there was a proper allocation of the available natural resources. Other environmental gain was tourism encourage soil conservation which accounts for 44.4%. It is suggested that tourism can act as a catalyst for conservation and environmental protection because of the following factors: 1) it is generally non-consumptive and has less impact on natural resources than most other industries; 2) it is based on the appreciation of natural and cultural assets and has greater motivation to protect its resource base; and 3) it can provide valuable revenue and economic incentive to conserve resources which would otherwise be used in more damaging activities (WTTC and IHRA 1999). The government both local and central in collaboration with environmental agencies such as African Wildlife Foundation (AWF) and World Wilde Fund for Nature (WWF), has managed to properly allocated the resources for the betterment of present and future generation.

Table 1: Views by categories of respondents on the knowledge of tourism impacts (N=133)

From your experience in this area, agree or disagree on the following statements	Respondents	Tourism promotes culture of locals		Tourism provides employment		Tourism generate income		Tourism encourage cross-cultural activities		Consumption of natural resources		Ecological sensitive areas		Wildlife habitats destruction		Agricultural goods and services		Air pollution	
Variable	N	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
LOCATION:																			
Mto wa Mbu	45	3.7	1.0	4.2	0.8	4.0	0.9	4.0	0.9	4.1	0.3	4.0	0.8	4.2	0.9	3.8	1.0	3.4	1.8
Majengo	38	4.1	0.9	4.5	0.5	4.3	0.8	4.4	0.5	3.8	1.4	3.9	1.1	3.6	1.0	3.6	1.7	3.5	1.8
Kilimamoja	39	3.8	1.1	4.1	0.8	4.2	0.9	3.7	1.1	3.4	1.7	3.7	1.9	4.0	0.9	3.9	1.0	3.6	1.7
Qurus	11	4.2	0.9	4.4	0.5	4.5	0.5	4.0	0.9	4.1	1.9	4.6	1.0	3.9	2.0	3.3	1.9	3.4	1.8
SEX:																			
Male	75	3.9	1.0	4.2	0.9	4.4	0.5	3.9	1.0	3.9	1.1	3.7	1.2	4.1	0.8	3.6	1.0	4.2	0.4
Female	60	4.0	0.9	4.1	0.8	4.5	0.6	4.2	0.9	4.0	0.4	3.9	1.4	3.9	1.0	3.8	1.1	4.2	0.7
EDUCATIONAL																			
Primary	24	3.9	1.0	4.1	0.8	4.4	0.5	4.1	0.8	4.2	0.2	3.9	1.5	3.7	1.1	3.6	1.0	4.1	0.6
Secondary	65	4.1	0.8	3.9	1.0	4.4	0.5	3.9	1.0	3.8	1.6	3.8	1.0	3.9	1.0	3.7	1.1	3.9	1.3
High School	19	4.0	0.9	4.2	0.9	4.5	0.6	4.4	0.5	4.0	0.7	4.0	0.9	4.0	0.8	3.9	1.O	3.8	1.0
Tertiary	13	3.6	1.1	4.1	0.8	4.3	0.8	3.9	1.0	3.0	1.8	3.4	1.1	3.7	1.3	3.5	1.2	3.7	1.1
Informal	11	4.3	0.8	4.1	0.8	4.4	0.5	4.0	0.9	3.9	1.1	4.0	0.9	3.0	1.9	3.9	1.0	4.1	0.6
AGE:																			
16-24	49	4.5	0.5	4.0	0.9	4.2	0.8	4.4	0.5	4.0	0.5	4.1	0.9	4.0	0.8	4.0	0.8	4.6	0.7
25-34	46	4.2	0.9	4.2	0.8	4.6	0.5	4.2	0.9	4.1	0.9	4.0	0.8	4.4	0.6	3.9	1.2	4.5	0.9
35-44	38	4.1	0.8	3.9	1.0	4.0	0.9	3.9	1.0	4.2	0.3	4.0	0.7	4.3	0.4	3.8	1.1	4.1	0.8
45-59	2	4.5	0.5	4.0	0.9	4.5	0.5	5.0	0.0	4.0	0.6	4.0	0.9	4.5	0.5	3.9	1.0	4.3	0.5
60+	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DURATION OF LIVING																			
< 10	46	4.6	0.4	4.2	0.8	4.5	0.5	4.1	0.4	3.8	1.6	4.1	0.9	4.3	0.5	4.5	0.5	4.4	0.6
> 10	31	4.1	0.8	4.3	0.8	4.5	0.6	3.9	1.2	3.8	1.9	4.0	1.0	4.2	0.8	3.9	1.2	4.6	0.8
Born here	58	3.9	1.0	4.0	0.9	4.3	0.8	4.0	0.6	4.4	0.8	4.2	0.6	4.1	0.7	4.0	0.9	4.5	0.7
TOTAL MEAN		3.9		4.2		4.4		4.1		4.0		4.1		4.0		3.8		4.1	

Table 2: Benefits of Tourism to the livelihood and environment of indigenous societies

Positive impacts	Frequency	Percent
Improvement of social services	77	57
Employment Opportunities	88	65.2
Create friendship	92	68.1
Encourage soil conservation	60	44.4
Proper allocation of resources	92	68.1
Natural resources conservation	106	78.5
Provides market for the local goods	80	59.3

Table 3: Negative impacts of Tourism on the culture and environment

Nature of impacts	Frequency	Percent (%)
Loss of cultural identity	94	69.6
Vandalism, Prostitution & crimes	81	60
Moral decay	70	51.9
Increases price of goods	55	40.7
Creates conflicts to the host	62	45.9
Spread of STDs	92	68.1
Increase street children & beggars	78	57.8
Increases dependency	71	52.6
Introduction of invasive species	36	26.7
Overutilization of Natural resources	69	51.1
Destruction of Ecological sensitive areas	81	60
Improper waste disposal	56	41.5
Deforestation	86	66

Tourism has influenced the society in both way, local quality of life and the sense of place. In fact the movement of the outsiders in any area could not be without impact. The level of impact can vary on various aspects. From the socio-economic aspects such as job generation by hotels /lodges was a very important impact of tourism in area. It is obvious that hotels and lodges are meant for the visitors who do not have home out there. The entry of outsiders obviously requires the home to live in for food and shelter and consequently local people have to work for it. Every hotel and quarters hold paid staffs and workers as per nature and size of their operations.

In the study area that, local people either eat or wear what they are habituated of doing within their culture or they copy some favourable items from tourists who are in repeated contact with them. In case of Mto wa Mbu too, more than 60% of respondents have felt changes in their dressing patterns as a result of the tourism. Nearly 22% of the respondents have realized small change in food habits and tastes. Actually the food habit and taste to which the local people are accustomed for many years was very hard and needless to be modified though the need for tourist's satisfaction have diversified the menu too. Such a diversification of menu is very important impact from the cultural point of view. The group of nearly 15% realized all of the changes stated above and also added that the local people's views toward their daily life too have got some modifications. It is what takes place inside one's attitude. Money consciousness caused by tourists' spending pattern is what made them change professions. The information about foreign culture, which the local people can daily observe has made them attracted toward the accessories like cameras, vehicles, watches and other similar goods as well as the intention to go abroad to enjoy foreign life style and earn money.

Vandalism, prostitution and crimes were another negative impact observed in the study area that accounted 60% of all respondents (Table 3). This implies that tourism activities increases crime rate such as robberies, pick pokers and drug trafficking. Tourism also increases number of street children, beggars, and dependency ratio by 57.8% and 52.6%, respectively. In recent decades there was an abrupt increase of the number of beggars in streets and number of street children became high. Moral decay was another negative cultural impact that was evident in the area, and it accounted for 51.9%. Moral Decay has something do with uncertainty, opportunity, and money: people, unable to trust longstanding honor systems, begin to steal and lie to one another, or worse, become robbers. Another negative impact that was evident and reported by the respondents was the increase of price of goods and services as reported by 40.7% of the entire respondents. Tourism was recorded as an economy that imposes many impacts of price of goods to the local people; this was precisely because the goods are bought with foreign currencies, in which it has a high value compared to Tanzanian shillings.

Tourism lead to deforestation (66%), in fact the outlook of the area has taken a new look. Uncontrolled tourism development also damaged the ecologically sensitive areas and ecosystems which was agreed by 60% of the respondents. Damage arises primarily through pollution, frequently movement of the vehicles to those areas, overuse and inappropriate practices. Other environmental impacts observed in the study as shown in the above table include destruction of wildlife habitats (58.5%). Game viewing and increased pressure on endangered species from hunting and trading activities, domestic and hotels consumptions of the wildlife resources they together are marked as having many consequences on the wildlife habitats. Overconsumption of available natural resources (51.1%) was another environmental impact that was revealed in the area; over consumption of natural resources such as freshwater, energy, land and marine resources can lead to resource depletion and degradation. The solid waste disposal was another remarkable environmental problem in the area because the sites for garbage disposal are inadequate in most of the areas. This waste disposal and untreated sewage system was tallied 41.5% and 34.7% by the respondents, respectively.

The respondent's comments on how to improve the sector

The question was responded by respondents and it showed a wide division of responses. The question was "what is your comment about the socio-cultural and environmental impacts of tourism in your area" as the main economic activity in your area. The responses were as follows; 65.9% said there must be provision of Education and Training to indigenous people about their culture and incoming Tourists about the culture of the place they are visiting, 54.1% suggest that there must be severe and proper allocation of the laws on cultural distortion, 53.3% need the cultural awareness in the society (Table 4). And 44.4% of the total respondents suggest that the indigenous people should be empowered so that they can be able to overwhelm those tourism changes, while the responses also shows, 44.4% want the government to provide a proper code of public dressing, the 37.8% of the respondent was in favor that the government to control number of tourists so as to reduce the extent of the impact, again 37.8% of overall respondents was in demand for the indigenous people to hold the code of conduct of their culture and the parents to raise the cultural loyalty to the upcoming generation. Lastly, 34.8% of the total respondents need the government and international organization to improve and provide the social services that cater the needs and wants of the people

Table 4: Respondents Comments on the impacts of Tourism in the area

Comments/recommendations	Frequency	Percent
Provision of Education and Training	89	65.9
Empowerment of indigenous people	60	44.4
Parents to rise Cultural loyalty	51	37.8
Control number of tourists	51	37.8

DISCUSSION

The finding of the study suggests that tourism play a key role in the development of the remote areas. Development of tourism activities may help in the diversification of the economy, and provide viable alternative livelihood opportunities for the indigenous people. In view of limited industrial growth in the area, tourism became a potential source of income generation in the remote regions and generates employment opportunities to the local communities (Kibicho, 2004). Over recent years the area has experienced significant changes as a result of tourism growth. Since 1990, there has been a tremendous growth in visitation number (Muganda et al, 2010). Generation of new economic activities like hiring of cycles, parking of vehicles, taking care of tourist's goods for the time being, and guiding have come into view (Mahony & Van Zyl, 2002). These events have not been wholly institutionalized as a separate trade but make available an extra profit to the indigenous population. This is similar to results highlighted in previous micro-level studies by Timothy (1999), Kulindwa (2002), and Manyara and Jones (2007).

Such new areas of income emerged as a result of tourism which is not only and economic phenomena but an influential cultural phenomenon too because engagement in different activities brings changes in the daily life styles. Employment generation and formation of new economic activities raise the income of the people which obviously affects living standard (WTO, 2009). The jobholders both private and government involve this category. The generations of the jobs in the private sector are due to tourism but they are not paid directly by the tourists. And the 43% farmers though do not deal directly with tourist have felt an increment in income around two to three dollars a day due to the increased demand of food grains to feed the tourist flow. Nearly the half 49% are found to be directly benefited from the tourists. The small part involving hoteliers have made money up to large extent above ten dollars a day in some season. All these economic impacts (employment and new economic activities) of tourism affect daily life style of the people and consequently the social cultural behaviours slowly but surely. Studies done by Acharya (2001) and Hall (2006) were in line with the findings of this study and they also come to the conclusion that the economic entity has highly affected the life style of the indigenous people.

In the tourist areas of Mto wa Mbu and Karatu, a shift in the composition of the resident population has occurred to include a large number of migrants from the interior villages due to potential employment in the tourism industry. Most of these people are engaged in selling artisanal pieces, handicrafts and garments. It cannot be denied that tourism has also given a boost to local art and handicrafts; however, the commercialization of such arts and crafts has resulted in certain deterioration in their quality as they are being manufactured for bulk sale. At another level, cultural practices are being used as tourist attractions, such as dressing and food style, which have been given a certain orientation to suit the demand of tourists. Much of the spontaneity of these practices has been lost. Sawkar et al. (1998), Wantaee (2003) and Bura (2009) they also revealed that the indigenous culture has been drastically changing due to the interaction with the tourists. Their studies have also explored that the life of the rural people has been improving and giving the market to the local goods.

Moreover, some of the villages along the road have become very tourist-oriented and thus, shifted away from their traditional occupations. A couple of decades ago, these villages were predominantly pastoralist- oriented or agricultural-oriented. Tourism has increases land prices and encouraged locals to sell their land, thereby sharply increasing the competition for land in the area. Jones et al. (2007) concluded that tourism can accelerate the decline/increase of agriculture in the area, by providing a viable alternative for the lateral transfer of investment capital, land, and labor by the locals. It increases agriculture because it assures the producers the market availability for their products. In the area, land conversion from agriculture to non-agriculture uses has been observed. The study conducted by Western (2008), proves that the tourism activities has increases the pressure on the agricultural products as it provide the market for the good/crops such as rice, beans, maize, vegetables and fruits. Additionally, it was unlikely for them to associate such improvement with any other sector given that tourism is regarded as a very important economic activity in their village particularly in activities such as tour operations, curio shops, and handcraft sales. Local people had different views and perceptions about the impacts of tourism and what they need to be done to improve it. They believed tourism was a factor of acculturation which affects attitudes, alters popular beliefs, changes mentalities and spreads new concepts relating to work, money, and human relationship. They further believed and agreed that tourism activity can destroys ties that bind people to their faith, religion and aesthetics. Local youth in many cases emulate the visitor's behaviour and sometimes social conflicts arise. Positively, tourism was perceived as a tool bringing people of different cultures together, provide a direct contact between the two parties of the culture (Cole, 2006). It provides an opportunity for friendly and peaceful dialogue leading to better understanding between people and nations.

The environment is being increasingly recognized as a key element in tourism. Many community attractions and tourism offerings have a reliance on the natural and man-made resources (McLaren, 2003). The environmental impacts of tourism on community can take the form of both the quality of the physical environment and access to these resources in which positive environmental impacts of tourism on a community (Mahony and Van Zyl, 2002). Tourism provides a reason to preserve the natural scenery and man-made historic sites, ecological sensitive areas, traditional towns and neighborhoods and protected areas. Eco-tourism put much effort in establishing the principles of green environment (Honey, 1999). On the contrary, negative environmental impacts which are frequently highlighted include littering, overcrowding, traffic congestion as well as pollution of, water and soil along with the deterioration and overuse of natural resources as a result of the constructions of tourism services, such as erections of hotels, lodges and other accommodation facilities. Tourism increases pressure on the land and other resources such as water. In the study area land has become a major natural capital especially those who resides near the road. There are two main reasons of why pressure on the land has drastically increased. Firstly, is that tourism is a growing industry, hence most of the investors are searching for areas that they can construct facilities like lodge, hotel or curio shop. Secondly, because the land is equated to the tourism money value and especially in form of dollar, so many people want to make money from it.

Along with the gradual development of tourism, construction of different structures is necessary. This area was full environmental resources and still is. In fact the outlook of the area has taken a new look, this has also been concluded in the study of Muganda et al. (2010). It is the most important environmental impact induced by tourism. Besides the people both the tourists and the local experience air pollution caused by the dusty roads passing the communities land and some of the poor conditioned vehicles. The solid waste problem was not so remarkable because the site for garbage disposal is adequate in some places. The areas like Mto wa Mbu and Karatu town experiencing littering along the main road. Generally, the visitors consume the locally available food and sometimes they carry extra food packets that they can consume on the way hence they throw the remains of those foods. Camping and tenting are favored in some parts of the area, for example in small towns of Karatu, Kibaoni and Mto wa Mbu. The establishment of those tents has impacts on the general quality of land. Due to the tourism activities in the study area, many people attracted to this area for business and other social activities. Increased number of people in the area increases littering.

Combining the quantitative results with qualitative responses from the survey and interviews with key decision-makers has identified overlapping factors that influence the socio-cultural and environmental. First, local people's views were based on the creation of employment opportunities and improvement of life. The concern was that tourism has raised the prices of goods and services and consequently the cost of living. Secondly, there was a concern that tourism contributes to the increases in pressure of environmental resources. Third, concern was that, tradition has now been abandoned by the present generation. Fourth, there was a general feeling among local people that tourism contributes more towards improving the livelihood of those living in sub-villages close to the main road rather than the village as a whole. The study also comes into conclusion that the improvement and changes of the life style in the study area was not based on tourism activities per se, other economic and social activities such as agriculture, pastoralism, trade and commerce has also contributed to the changes. Muganda (2010) also portrays that the life of the most of the rural people depends on different social activities including tourism in which interactions can be observed.

CONCLUSION

Basing on the discussion presented, there are several questions that the study aimed to answer, all of which was presented. Study come into the conclusion that poorly planned tourism can mean that indigenous are invaded by foreign visitors with different values, disrupting rural culture and their environment, following by the decline in participation in rural traditional and cultural practices. Traditional houses are replaced by modern buildings, as the local culture is eroded. The agriculture which was the basis of traditional life is replaced by, and becomes secondary to tourism. Traditional dressings are becoming a popular tourist attraction in the area, and traditional farming practices in have both decreased in recent years.

The higher standards of living in urban tourist destinations have caused emigration from nearby rural neighbours, resulting in changes in the demographic structure and possible culture shock. Furthermore, employment and education can have a negative social impact. The younger generation gained prestige that rivals that of their elders as they gain experience, jobs and money from tourism. It is widely recognized that such negative impacts on rural communities have become stronger, and that tourism must be modified to give rural people its benefits. Tourism environment impacts that is determine with the carrying capacity constraints in the tourism sector concluded that the natural resources in the case study are in a sufficiently pristine state, and of such high aesthetic quality, that a period exists in which environmental deterioration can occur without an adverse effect on tourism. However, the problem is that the duration of this period cannot be predicted and with increasing environmental pressures, rising environmental sensitivity, and without compensatory environmental management, adverse effects may be felt sooner than later. On the other hand, tourism has the potential to create beneficial effects on the environment by contributing to environmental protection and conservation. It is also, a way to raise awareness of environmental values and it can serve as a tool to finance protection of natural areas and increase their economic importance

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ASSESSMENT OF LAND USE CHANGES IN MONDULI AND SIMANJRO DISTRICTS, NORTHERN TANZANIA

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ABSTRACT
This paper examined the dynamics and magnitude of land use changes in Loiborsiret, Mswakini Juu and Mswakini Chini villages. Data were collected using Remote sensing techniques, topographic maps analysis, questionnaire survey and physical observations. Results indicate that there has been expansion of cultivation and settlements/settlements into grazing or dispersal areas. These changes have led to the reduction of the grazing and dispersal areas by 9% while the settlement areas increased by 8% provide time frame for this change. High human population growth mainly due to immigration and land sale are the major drivers of land use changes in the area. The results of this change have led to increased human-wildlife conflicts and blockage of wildlife migration routes. The paper recommends the need for re-development of integrated participatory land use plans which will minimize competition for resources and sustaining the range land; development of Wildlife Management Areas, enhancement of destocking campaigns, and family planning advocacy to reduce demographic pressure.

Key words: *wildlife corridor, land use, conservation, wildlife management areas, northern Tanzania.*

INTRODUCTION
Land use change as a central component of global environmental change with direct implications for the earth's climate, ecology and human societies; is of great concern to national and international policymakers (UNEP, 2003). This is because most land-use changes are now believed to be driven by human use and because land-use practices themselves also have major direct effects on environmental processes and systems; thus understanding past changes in land use and projecting future land-use trajectories requires understanding the interactions of the basic human forces that motivate production and consumption. Hence being able to project future states of land cover is a requirement for making predictions about other local changes (Ibid).
Gaining a better understanding of the ways that land-use practices are evolving is a

priority concern of the global change research community. Research on how human factors interact in driving land use will improve projections of land use changes and their impacts to environmental changes. For the economic, social, and behavioral sciences, it will also provide an opportunity for basic research into the factors that shape individual and group behavior. The characteristics of land use and changes have important impacts on climate, socio-economic, and the diversity and abundance of terrestrial species (Foley, 2002).

In East Africa, Serneels et al (2001) observed that land use policy is a major factor influencing the conversion of rangelands to cultivation in pastoral areas in this region. They argued that policy instruments in particular affect the decision-making process of agro-pastoralists and therefore modify land use changes and their impacts on the ecosystem (Homewood et al., 2002).

This paper aimed at assessing (i) the extent of land use changes in the area (ii) identify causes of these land use changes and (iii) assess the implications of these land use changes.

MATERIALS AND METHODS

Study area

The three study villages of Loiborsiret, Mswakini Juu and Mswakini Chini are found in Simanjiro and Monduli Districts respectively (See Fig. 1). These villages lie between Latitude 3^0 20`and 5^0 1’south of the equator, and between Longitudes 3^0 34’ and 43^0 East. The altitude ranges from 560 to 2,123 meters above sea level. The selection of these villages was based on their role as wildlife migratory routes and as villages experiencing frequent land use conflicts

The rainfall in the study area is bi-modal with short rains occurring from November to December followed by a dry spell and by a long rains season from March to May. The short rains are very unreliable and show a high spatial variation. Long rains are more reliable both in distribution and total amount. Rain averages to about 650 mm per annum, but can vary widely from year to year (TANAPA, 2001). There is relative relationship between rainfall and altitude in this landscape whereas lower altitude areas tend to receive lesser than higher areas (Mwalyosi, 2001). Mean maximum temperature is 27˚C and minimum temperature is 16˚C. The extreme minimum is 4˚C in July and the highest maximum 40˚C in January. Humidity in October falls to 35%, indicating very dry conditions (OIKOS, 2002).

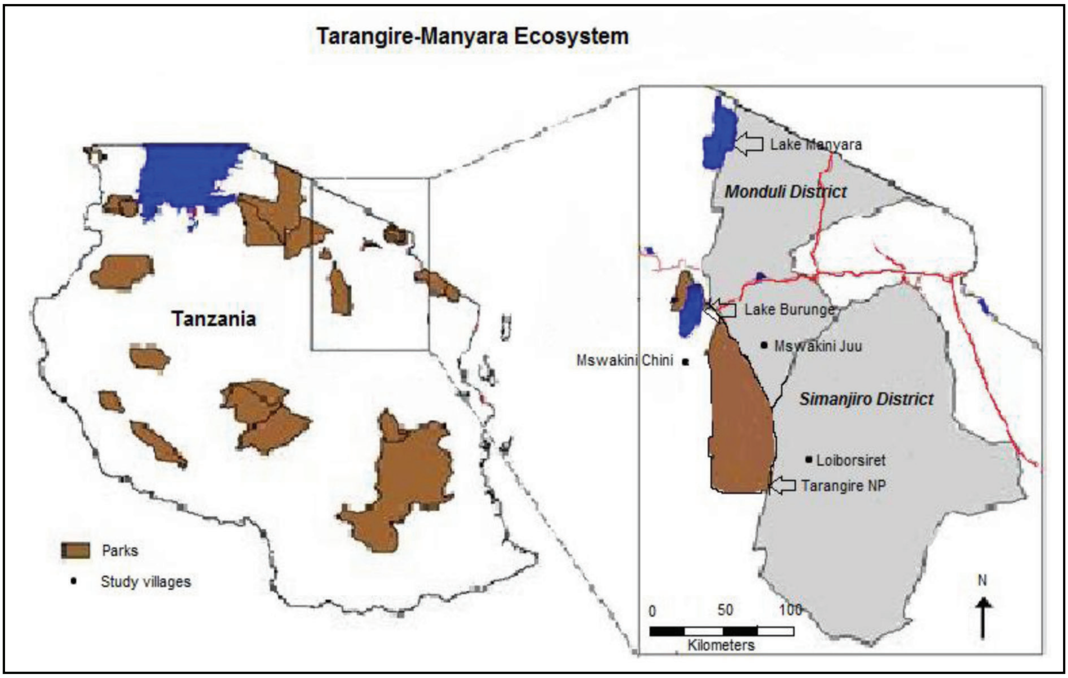

Figure 1: The study area

Data collection

Combination of four methods were used; Analysis of satellite imageries and topographic maps; questionnaire surveys, and physical observations.

Satellite Imageries

Analysis of satellite imagery was done as follows: Two Landsat TM scenes (path/row 167/63 and 169/64 of November, 2005) and two corresponding Landsat ETM+ scenes (February, 2010) acquired from United States Geological Survey (USGS) were analyzed.

Topographic Maps

Topographic maps with 1:50,000 scale were acquired and used during the physical field visits around the villages. After aligning the sheets, a separate piece of paper was used to map the changes; these changes were later overlaid into the land use map (manually) and the new map depicting the changes was drawn. The changes recorded from this map were later checked with the map from the satellite imagery source. The similarity between the two was not very big and in reality this map represented the true and actual situation as it in the field.

Questionnaire Surveys

Household questionnaires were used to collect data particularly for impacts of land and land cover changes, magnitude of the effects and future suggestions. Simple random sampling was done to get the representative sample. A total of 90 households were interviewed per each village. Before questionnaire administration, the questionnaires were pre-tested in Loiborsiret village. This was meant to improve the clarity of questions and questions which looked ambiguous were either removed or recasted.

Physical surveys

This technique was for the purpose of ground truthing. This was performed intentionally to cross-check the data acquired through remote sensing and topographic maps. Ground truthing involved counting of visible new farms, settlements, and extent of encroachment in certain habitats (e.g. grazing zone, cultivation area or settlement zone).

RESULTS AND DISCUSSIONS

Land use changes and their associated causes

Land use changes in the study area were assessed between 2005 and 2010 (See Tables 1). For each village, there were notable differences. The causes for land use changes (See Table 2) as perceived by the households varied from one village to another. For example in Mswakini Juu, the critical causes were land purchase (27%) and drought (26%). In Mswakini Chini the causes were land purchase/sell (23.9%) and immigration (23.3%). In Loiborsiret causes were immigrants (47.4%), inducements given to village leaders by individuals and/or investors (corruption) (22.2%), and land purchases (20.2%).

Table 1: Land use changes between 2005 and 2010

Village	Type of land Use	Year				
		2005		2010		
		Area (Ha)	Area (%)	Area (Ha)	Area (%)	Percentage change (+/-)
Mswakini Juu	Grazing	8840	71.2	8320	67.4	-3.8
	Settlements	2268	18.4	2862	23.1	+4.7
	Cultivation	1300	10.4	1186	9.5	-0.9
Mswakini Chini	Grazing	11780	81.7	10800	74.7	-7.0
	Settlements	2002	14.0	2700	21.8	+7.8
	Cultivation	624	4.3	906	7.3	+3.0
Loiborsiret	Grazing	40500	67.1	30400	50.4	-16.7
	Settlements	5800	9.5	13800	22.8	+13.3
	Cultivation	14200	23.4	16220	26.0	+2.6

Table 2: perceived main causes of land use changes

Village	n	Causes (%)				
		Drought	Immigrants	Land purchase	Corruption	Invasion
Mswakini Juu	90	17.1	20.1	27.2	13.2	22.4
Mswakini chini	90	22.1	23.6	24.4	10.3	19.6
Loiborsiret	90	10.2	26.2	20.2	22.2	21.2
Average	90	16.4	23.3	23.9	15.2	21.0

Mswakini Juu

Results indicate that residential area has increased by 23.1% between 2005 and 2010 (See Table 1 and Fig. 2a & 2b). Grazing and cultivation areas have been reduced by - 3.8% and - 0.9% respectively, whereas settlements area has increased by + 4.7%. These data suggest that, grazing and cultivation areas have been reduced largely due to an increase of settlements area. Settlement expansion was due to either immigration/ invasion or allocation of new plots/farms by the village authority. New settlements which are found at areas zoned for grazing, especially at the South-east of the village, near to Lolkisale Game control Area, which has to a greater extent changed the normal livestock dry season grazing area. The impact of this is reduction of grazing plain. Besides, wildlife wondering in this area for watering points has been blocked.

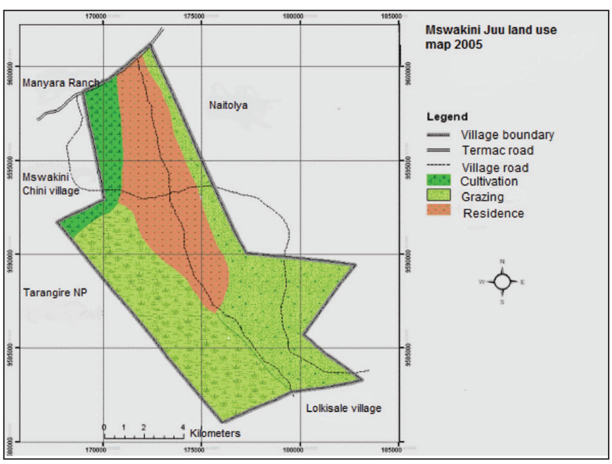

Figure 2a: Land use in Mswakini Juu in 2005

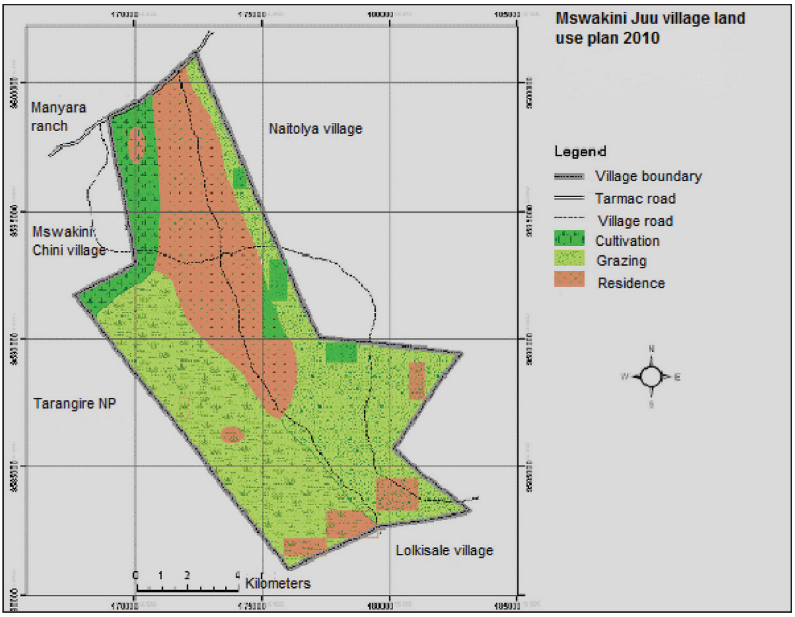

Figure 2b: Land use in Mswakini Juu village land use 2010

Sachedina (2009) observed the increased population at the area around Manyara ranch as being attributed by people's higher expectation and speculation for consolation scheme from Kwakuchinja Wildlife Corridor Project being implemented by Monduli District Authority, Tarangire National Park and African Wildlife Foundation. On the other hand, Kisui (2008) attributes the increased population number in the area with the booming of tourism business around Minjingu and Olasiti villages. Furthermore, International Livestock Research Institute (ILRI), (2009) observed the availability of all-time water source at Nguvu-Kazi charcoal dam at the village to have attracted livestock keepers from other areas during severe or bad seasons and settled at areas adjacent to Manyara ranch conservancy.

The positioning of Manyara ranch as a conserved area has also impact on attracting migrating pastoralists. Foley, (2007) observed that the availability of grass especially during high dry spell, than its neighbors; has made the ranch to be a grass-refuge and attract grass poachers from the adjacently situated villages.

On the Eastern side of the village close to Naitolia village boarder, there was a sprawl of new farms cultivating mainly legumes varieties which has replaced the traditional maize and beans agriculture. The common cultivated varieties are Lablab (Ngwara), Greengum (choroko) and commonpeas (Kunde) which have high drought resistance capability. Farmers from Naitolia village, where cultivation of these varieties was widely practiced, had started to encroach the grazing area at Mswakini Juu village and establish small farms (at average of 3 hectares) and seasonal settlements.

Data from Monduli District indicates that cultivation of legume crops has become common and popular to the extent of attracting more people from neighboring towns of Babati, Karatu and Arusha. There has been an increase of 30% for land cultivated for this type of legumes between 2005 and 2010 (DALDO Monduli, 2011). This land use change, at the center of the traditional wildlife migratory corridor; has a negative impact to the natural wildlife migration between Tarangire and Lake Manyara National parks. The presence of the farms has created a barrier between the two parks and isolated Manyara ranch which is the hub between the two parks (Sachedina, 20008). He further observed that, presently resident wildlife species like elephant, giraffe, wild dogs and wildebeest at Manyara ranch conservancy have been denied their natural breeding and calving opportunity at Lolkisale plains by these farms. Accordingly, this is a serious habitat fragmentation as a result of uncontrolled land use change emanating from livelihood option strategies. Satellite imageries data indicate that the size of the corridor has decreased by 33% from 6 km wide in 2005 to merely 2 km wide in 2010 (Ibid, 2009).

Mswakini Chini

The land use changes in Mswakini Chini were also clear in all zones (i.e. cultivation, grazing and settlements). Field data indicates that, settlements and cultivation areas have increased by 7.8% and 3% respectively, while grazing area decreased by 7% (See Fig. 3a & 3b. These changes may be due to a number of factors; Firstly, high trend in opening-up of new farms at both grazing and settlement zones; Secondly, the presence of illegal settlements at cultivation zone near to Manyara ranch; thirdly, abandonment of farming activities close to western parts of the village and unusual establishment of farming activities at the center of the village. The 2010 data from satellite imageries indicates development of farms at the western part of the village as compared to 2005. These new farms were all illegal as they were located at the boundary of Tarangire National Park. The location of the farms has created blockage for wildlife migrating out of Tarangire Park (Sachedina, 2008). The wild animals moving from Tarangire to Lolkisale or Burunge cannot move out since their natural route has been blocked. As a result, wild animals have to find long routes around Lolkisale or Naitolia villages.

Household respondents attributed land use changes with corruption by village leadership which allocated the land without following procedures. The allocated people have converted the land into a big farm (28 ha) and they grow legumes varieties of Lablab, Greengum and Commonpeas. The presence of this big farm at the centre of the village (i.e. the centre of settlement zone) has been caused by land sell. Two big and prominent families sold their land and decided to relocate at Kiteto; the buyer of the land decided to change the land use to cultivation. Conversion of land use from grazing to cultivation, due to corruption is increasingly becoming a serious problem in the village. Sachedina, (2008) noted that the present trend of land use conversion and its impacts to large herbivores migration at Tarangire National Park is threatening the connectivity with its dispersal areas at the northern side.

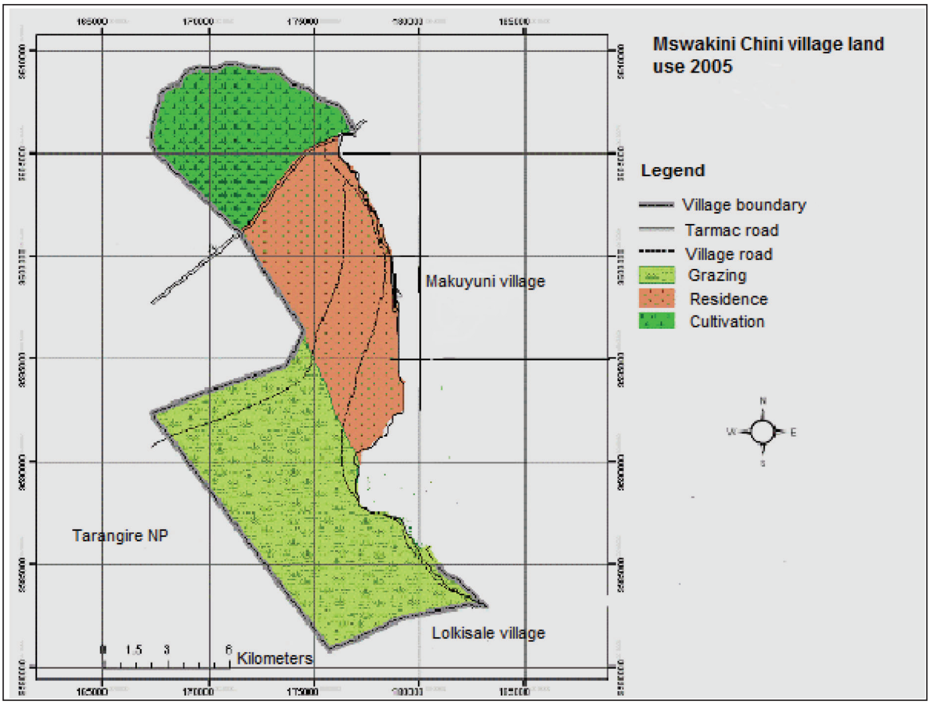

Figure 3a: Mswakini Chini village land use 2005

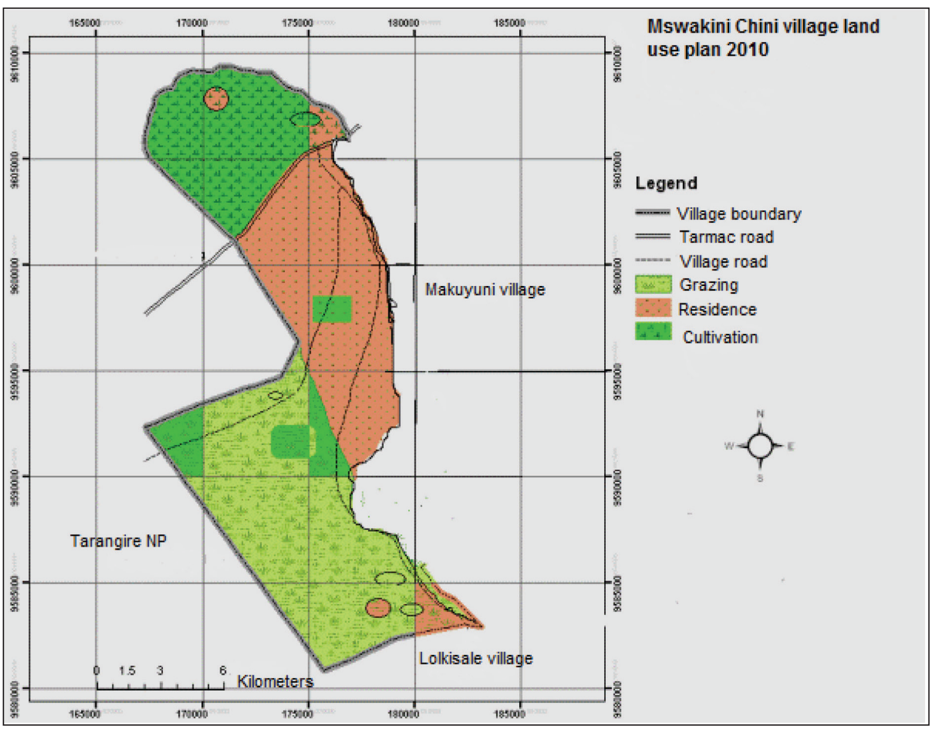

Figure 3b: Mswakini Chini village land use 2010

The observed new settlements south of the village, close to Lolkisale were reported to have moved to the area in 2009-2010 during the period of severe drought. They settled at the slopes of mount Lolkisale which extends to Mswakini Chini and where water for life and livestock is available. It was reported during the field visit that they have been granted official permit as residents after their two years' stay in the area.

Another segment of settlement, which was reported to be illegal, was found further to the South of the village. This is a group of illegal settlements who were evicted from Lolkisale proposed WMA area. They illegally established their permanent settlements at the centre of the forest; data from informal discussion with village leaders reported that these settlements apart from engaging in small scale farming; they also engage in poaching and robbery practices to tourist-hunters at the nearby Lolkisale Game control area.

Loiborsiret

The field data indicate that, in Loiborsiret land use has also changed in all zones (i.e. grazing, settlements and cultivation areas). Settlements and cultivation areas have increased by 13.3% and 2.6% respectively, while grazing area has decreased by 16.7% (See Fig. 3a & 3b). The differences of land use changes between different zones may be due to nature of land ownership, whereas grazing area tends to decrease because it is perceived as a public zone. The noted changes can be seen in a number of scenarios: Firstly, increase of agriculture/cultivation; Secondly, increased settlement/population; Thirdly, marginally decreasing of grazing area and closure of traditional cattle routes; and lastly, closure of traditional wildlife migratory corridors particularly those heading to Mkungunero game reserve area, Terat calving plain and Emboreet plains.

Land use changes between 2005 and 2010 show a drastic decrease of grazing land. The area has decreased from 67.1% to 50.4% at the span of five years. The situation in this village is seen critical than the rest of the study villages. The field data suggests that grazing area has decreased due to an increase of areas for cultivation and settlements. The results from household survey attributed the expansion of agriculture/cultivation with increased invasion by immigrants from outside the village. Land use changes indicate that, at the center of the village (where settlement is concentrated), and where there is a permanent water well; the situation between 2005 and 2010 is different and horrifying because, nearly seventy percent (70%) of the grazing land has been converted to cultivation. Additionally, according to household respondents (59% n=90), part of grazing area has been taken by miners who used to mine (Rhodelite) at Kaangala hamlet. They further argued that, after the gemstone exhausted, these people had no other option other than engaging in agriculture and they buy land from the local people at the village for cheaper prices.

At the centre of the village; where the permanent water well is located, the source is been overused and the catchment area is highly degraded. The 2009-2010 severe drought never experienced before 1961 has attracted cattle and people to migrate into this village in search of water. As a result, the settlement pattern zone at the village has changed drastically with increased squatters at the centre of the village.

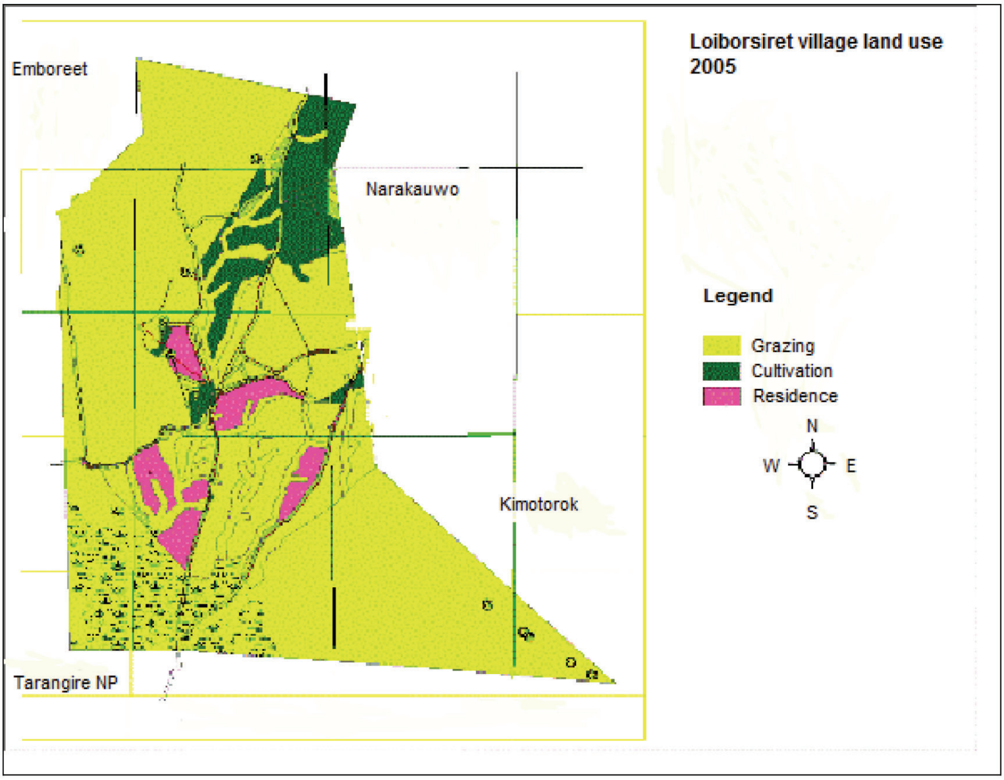

Figure 4a: Loiborsiret village land use map 2005

Impacts of Land use Change

The major impacts for the changing land use as perceived also differed from one village to another. The most critical were; Threat to life (40.3%), increased conflicts (33.3%), increased poverty (27.2%) and unplanned settlement (18.6%) whereas the minor was land degradation (See Table 3).

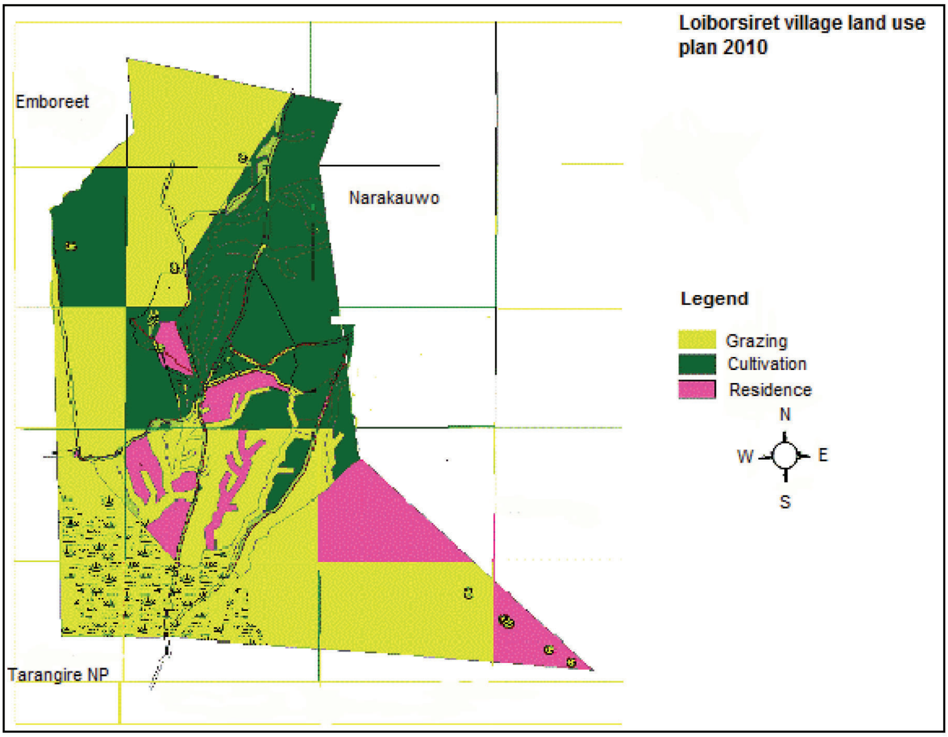

Figure 4b: Loiborsiret village land use map 2010

Increased conflicts

Land use changes were attributed to increased conflicts in the study area. For instance, 29.3% (n=90) of respondents from Loiborsiret village stated that, conflicts have increased in different forms (i.e. livestock keepers against farmers, farmers against wildlife) and too much time is spent in adjudication and negotiation meetings instead of engaging in production activities. However, it is difficult to establish the direct relationship between land use changes with increased conflicts. It is known that conflicts can have multiple causative factors, including oppression, denial or misunderstanding.

Unplanned settlement

Increase of unplanned settlement was mentioned (18.6% n=270) as one of the major impacts of land use changes in the study area. This phenomenon can also be seen through land use maps whereas there is mushrooming and extension of settlements out of settlements zone. For example, in Mswakini Juu there has been mushrooming of settlements at the southern part, whereas previously the area was zoned for grazing. This has caused reduction of grazing area and blockage of migratory routs for wildlife and livestock.

Threat to life

Households respondents also perceived (40.3% n=270) that, increased incidences of life threatening by wildlife have increased tremendously. This has been attributed by the closure or disconnection of wildlife migratory corridors especially to the calving areas during the wet season.

Suggestions to Mitigate Land use Changes

Respondents were asked to suggest appropriate measures for addressing continued land use changes in the area (See Table 4). Various measures were suggested by household respondents, informal respondents (i.e. elders, village leaders). The Households suggestions were; promotion of education especially secondary education to the community of the study villages. This suggestion imply that, education is a problem in the study area, this can be vivid in socio-economic status of the study villages where illiteracy rate is high where almost 70% of the people were reported to have primary education. They further perceived establishment of WMA as a way to both control land use change and means to benefit from wildlife resources. Survey of private plots was mentioned as a way of having reliable land security when they are enforced with customary land titles. Training Village Game Scouts (VGS) to undertake patrols at the villages' boundary to check illegal migrants and chase away marauding wildlife was also perceived as a way to enforce the agreed land use plans. Relocation of illegal immigrants was also mentioned as a way to stop any future intended migration. The elders and village leaders` views were nearly the same as those of households. About 69% (n=12) suggested intensification of patrols so as to control the illegal migrants to the villages boundaries. Issuance of customary title deeds, training of VGS, introduction of consolation fee (compensation fee) and establishment of WMA are the main suggestions.

Table 3: Perceived land use change impacts

Village	n	Causes (%)				
		Drought	Immigrants	Land purchase	Corruption	Invasion
Mswakini Juu	90	17.1	20.1	27.2	13.2	22.4
Mswakini chini	90	22.1	23.6	24.4	10.3	19.6
Loiborsiret	90	10.2	26.2	20.2	22.2	21.2
Average	90	16.4	23.3	23.9	15.2	21.0

Table 4: Suggestions for mitigate continued land use changes

Informal respondents	Household respondents	TANAPA officials
Intensify patrol	Promote education	Establish CBV's/WMA
Enforce by-laws	Establish WMA	Train village technicians
Train Village Game Scouts	Survey private farms	Relocate the immigrants
Establish Wildlife Management Area	Participatory land uses	Easement payment
Facilitate customary titles	Facilitate customary titles	Introduce (PES)*
Introduce compensation fee	Train VGS	Introduce consolation fee

TANAPA officials suggested establishment of a WMA as a way of bring to communities the benefits of conservation through establishment of Conservation-base-ventures (CBV's). They further argued that, when a WMA is in place, land use change problems will be addressed as a unit issue (i.e. a WMA). They also suggested training of Village Technicians (VT's) to be permanent village custodians to oversee and immediately report any act of violation of agreed land use plan of a particular village.
Easement payment was also suggested as a way to compensate the households who resides Mswakini Juu and Mswakini chini villages. This will probably keep in opening-up the Kwakuchinja wildlife corridor. Introduction of both Payments for Environmental Services (PES)-which is the payment for services provided for by a particular source. For example, payment for the free land area forsaken by the village as a service for the wildlife movement. And consolation fee for the affected human beings by wildlife was perceived as a mechanism to encourage villagers to maintain and conserve the migratory corridors.

CONCLUSION AND RECOMMENDATIONS

The study reveals that, to a large extent land use changes have occurred in the study area. Settlements and cultivation areas have increased by 8% and 3% respectively while grazing area has decreased by 9%. These changes indicate that grazing area has decreased due to increase of settlements and cultivation area. This has mainly caused by high rate of immigration into the area due to various factors (e.g. water availability and arable land) whereas immigrants have rapidly increased population size and hence leading to high pressure on resources (i.e. land resources). Other factors led to land use changes in the area included land sell, corruption among village leaders and drought. These phenomena have increased conflicts in the area and affecting the ecosystem in general whereas the natural water bodies have been depleted and blockage of wildlife corridors and leads into wildlife habitat fragmentation. However, it is possible to reverse the existing situation of land use changes and its impacts if appropriate measures will be applied. These measures include the need for re-development of integrated participatory land use plans which will minimize competition for resources and sustaining the range land; development of Wildlife Management Areas, enhancement of destocking campaigns, and family planning advocacy to reduce demographic pressure.

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ECOHEALTH SURVEILLANCE AS A TOOL TOWARDS DISEASE CONTROL IN GOMBE NATIONAL PARK, TANZANIA

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ABSTRACT

In recent years, human encroachment into protected areas has risen tremendously. Protected areas in the tropics are biodiversity hotspots which may act as a source of infectious diseases. Gombe National Park in Tanzania is not an exception; chimpanzees, close relatives to humans, have pathogens they can equivocally share with humans. Protection of fragmented habitats and attenuation of poaching has reduced the rate of decline of the Gombe chimpanzee population. However disease outbreaks have been a leading cause of Gombe chimpanzee population decline while potentially posing a threat to the health of people living in close proximity with chimpanzee (researchers, park managers, tourists and local communities close to the park) Ebola, respiratory diseases, polio, anthrax, simian immunodeficiency virus (SIV) and parasitic diseases have severely decreased the number of chimpanzees in Africa, and in some cases, result in negative impacts on human health. The Gombe Ecohealth project aims at early detection, preparedness and reducing the effect of infectious diseases in both chimpanzees and humans. In Gombe, employees' health program, park environmental hygiene and chimpanzee viewing health regulations are implemented through the Gombe Ecohealth program. Information from chimpanzee daily health observations, non-invasive fecal sample collection from each known individual chimpanzee and opportunistic necropsy tissue sampling provide opportunity to understand diseases and their effect in chimpanzees. Studies on SIV, gastro-intestinal parasite infections and the effect of stress levels on performance of chimpanzees are conducted through the collection and analysis of fecal samples. Furthermore, analysis of stream water collected throughout the catchment area reveals transmission dynamics of pathogens. All these efforts are aimed at understanding diseases transmission risk and disease effect; consequently designing better strategies for prevention and control of diseases.

INTRODUCTION

Primates and humans share broadly similar physiologic and genetic characteristics and hence are susceptible to pathogens that have the potential to cross primate-species barriers (Ruch, 1959; Brack, 1987). These pathogens are of interest to public health (Jones et al, 2008; Taylor et al, 2001) especially high-risk interface tropical forest; the habitat of most primates like chimpanzee (Morse, 1993). Monitoring of wild chimpanzees serves as sentinels for signaling pathogens that pose threats to human health in areas proximal to protected areas in many parts where these nonhuman primates inhabit (Wilson et al 1994)

Exponential expansion of human population and their activities such as ecotourism, encroachment and poaching within or into primate habitats have resulted in high potential for multi-directional pathogen exchange creating challenges for biodiversity conservation and global health (Gillespie et al, 2008).

Free ranging chimpanzees are particularly vulnerable to any decline in population number as they reproduce relatively slowly exacerbated by mortality due to disease outbreaks (Wallis and Lee, 1999; Lendeertz, 2010).

Although research and tourism bring human and chimpanzee into close proximity that is a risk for disease transmission, these activities benefits conservation through income generation and reduced poaching (KÖndgen et al, 2008). It is important to balance between diseases risk and benefits from tourism and research, by strictly abidiing to diseases prevention strategies.

Isolated disease outbreaks or in combination with other risk factors, can pose serious threat to the long-term persistence of mammal population; these risks are elevated as a population size decreases and or population isolation increases (Cleaveland et al, 2001). Hence diseases research should be incorporated in conservation programs of Chimpanzees.Gombe National Park hosts a continuous study of wild chimpanzee by Jane Goodall Institute for almost 50 years. Population declined from about 117-147 in 1960s to about 86-87 in 2005 (Pusey et al in press in Lonsdorf et al, 2006), and recovered to 98 – 106 in 2011. Past anecdote health surveillance has shown that disease outbreaks are associated with decline in the chimpanzees' population. Major disease outbreaks at Gombe include suspected polio in 1966; respiratory diseases in 1968, 1987, 1996, 2000, and 2002; and sacroptic mange in 1997 (Goodall, 1983, 1986; Mlengeya, 2000; Nutter, 1996; Pusey, 1998) (Table 1). To better characterize and manage the risk of infectious diseases, a non-invasive observational health-monitoring program was implemented in two of the three chimpanzee communities in Gombe in early 2004 (Lonsdorf et al, 2006).

Detection of both human and domestic animal parasites in wild chimpanzees necessitates more investigation on movement of chimpanzees, people (researchers, park staff and surrounding villagers), and sympatric animals such as baboons. Water sources in the park and villages (shared between humans and animals) are sampled to assess parasitic and bacterial disease risks, transmission mode and direction. In Gombe National Park various stakeholders of various disciplines such veterinarians, epidemiologists, biologists, law enforcement and administrators work together in holistic way to attain a sustainable conservation of the endangered chimpanzees as well as better public health. General management plan (GMP 2005), guidelines for viewing chimpanzees (Lukasik– Braum, 2008) and guidelines for visiting researchers (Collins, 2003) are examples of these strategies.

MATERIALS AND METHODS

Study site

Gombe National Park is a narrow strip of land covering 35 km2 bordered on the west by the Lake Tanganyika, on the east by rift escarpment and on the north and south by Mwamgongo and Mtanga villages respectively. The large part of the park consists of hills sloping westward from a rift escarpment 1,500 m above sea level. Gombe is home to seven species of non-human primates including chimpanzee (Wallis and Lee, 1999) and the park is restricted to researchers, ecotourists, park management staff and local field assistants (Wallis and Lee, 1999).Gombe has three chimpanzee communities namely Mitumba, Kakombe and Bwavi. Mitumba and Kakombe have been habituated and followed daily where only Kakombe community has been used for research and ecotourism since 1978; the Bwavi community is not habituated, but there is a team of experts monitoring for their health including noninvasive sample collection.

Daily observation

Gombe Ecohealth project collects a complete and standardized surveillance data on chimpanzee health for risk assessment and management (Lonsdorf et al 2006). Regular non invasive sample collection help to establish a baseline about what parasites/ pathogens are present in subclinical or clinical cases in wild chimpanzees. The information generated can be used to make science based decision at time of disease outbreak (Cooper, 1998; Travis et al, 2006)

Daily observation of the Chimpanzees is done by observing animals from a distance (Cooper, 1998). Non invasive sampling is done by collecting naturally voided material from the animals which is preserved in appropriate transport media. The hygienically collected samples are labeled for date, identity of the animal, time, type of sample, colour and consistency of the sample and the name of the collector.

In case of chimpanzees' fecal sample, the macroscopic observation to consider include colour ranges from yellow, grey, white, green, black and red while consistency ranges from solid, paste to watery state.

Quality of sample collected, macroscopic observation combined with the observation of the animals, microscopically analyzed sample will yield better results that are easy to interpret. The collected information is stored as hard copy and electronically such as IMPACT where information can be easily retrieved and analysed. Weekly observation record and sample collection gives the health status of individual animals observed (Cooper, 1998). In Gombe National Park, non-invasively sample collected are analyzed for gastrointestinal parasite (worm, protozoa and bacteria) (Gillespie et al 2008) and SIV (Santiago et al, 2002 and Lonsdorf et al 2006). Stress level of chimpanzee is analysed using fecal samples collected non- invasively which is also a measure of their welfare. Water samples and fecal samples from other species such as human (researchers and people from the neighboring villages), goat, sheep, domestic dogs and other primates like baboons and monkeys are collected for further investigation of diseases whenever resources are available (Gillespie et al, 2010; Goldberg, 2007).

Necropsy

A well performed necropsy examination provides helpful information in diagnosing a cause of diseases, cause of death, monitor the health of other animal in group or can help to provide forensic evidence.

Necropsy of non-human primates should be performed by an expert veterinarian, however, under field conditions is not always possible. In this case a trained biologist, ecologist, or ranger can help in performing a necropsy.

Personal protective equipment (PPE) must be worn and necropsy equipment must be appropriate, with enough sampling vials with various preservatives.

In Gombe National Park, we always perform chimpanzee necropsy because is the only time we get our hand on the animal and the more available sample preserved can be analysed later whenever diagnostic tool and finance is available. Chimpanzee necropsy provides significant scientific information on whether other in contact animals are at risk or possibility of zoonotic diseases outbreak.

DISCUSSION

This paper illustrates the importance of health monitoring as a tool for species conservation. Lonsdorf et al, 2006 pointed out that health monitoring of free ranging chimpanzee population is a significant tool in managing and conserving these endangered species. Observational health monitoring, non-invasive sampling and health guidelines for watching chimpanzee in Gombe have reduced the diseases incidences. Robbins et al., 2011, also showed that health monitoring together with immediate veterinary assistance has helped the recovery of Mountain Gorilla population in Uganda. Furthermore long term health monitoring provides sufficient data when dealing with clinical or subclinical disease cases and which might be contagious or non-contagious (Cooper, 1998) and it helps to inform the authority or public health on ways to control the diseases before it can spread further either locally, nationally or globally.

Very little information is available regarding the role of infectious diseases in the lives of chimpanzees in the wild (Nunn and Altizer 2006), despite chimpanzee being used for drug trials or in vitro diseases modeling for many years. In recent years emergence of infectious diseases has been linked with meddling with animals. Great apes share broadly physiologic and genetic characteristics thus a possibility of sharing pathogen that can cross border with human (Wolfe et al, 1998). Therefore as human encroachment towards fragmented chimpanzee habitat increased tremendously, emerging and reemerging diseases transmission should be addressed especially to people in close proximity to these non-human primates. In recent decades diseases transmission between human and non-human primates has caused a devastating situation in public health e.g. case of Ebola, Marburg and SIV and other respiratory diseases. Recognition of zoonotic diseases especially in high risk areas will help the public to give attention to prevent diseases from causing pandemic threat (Mazet et al, 2009).

Recently human zoonotic pathogenic parasites like Balantidium coli, Ascaris sp and Entamoeba hystolytica have been observed in Gombe chimpanzees (Gillespie et al, 2010). These parasites have never been observed previously in Gombe Chimpanzee, suggesting possible interaction between human and chimpanzee. Whether contact is direct or indirect through sympatric animals like baboon and velvet monkeys has not yet been elucidated (Daszak et al, 2000; Gillaspie et al 2010). More studies are required to understand transmission direction and effect of these diseases in chimpanzee and human.

Habituation of Chimpanzee for research have reduced poaching to greater extent and raise awareness to communities with regard to conservation of these endangered species (Goodall, 1986; Pusey et al 2008) and ecotourism is a means of income generation, which boost national economy and alleviate poverty at household level (Luvanga and Shitundu, 2003). In contrast to those benefit, habituation and ecotourism bring close interaction between human and chimpanzee, thus increasing risk for diseases transmission. However guidelines for visitors or and people working with chimpanzee are in place to reduce or prevent disease transmission (Collins 2003; Lukasik- Braum 2008). General Camp hygiene and proper law enforcement have contributed in reducing disease incidences in chimpanzee.Currently different diagnostic tools are available for detection of presence of diseases from non- invasively collected samples such as feces, wadges, and hair. To obtain good results the observational information should be serially combined with diagnostic tools to reach a judgment. Health monitoring is likely to increase its importance in near future as more diagnostic tools are available.

Opportunistic necropsies have provided more information on the cause of death of individual animals; furthermore necropsy has provided the understanding of the disease development in the animals together with other observation. For instance regular fecal sample collection has provided the understanding of existence of AIDs like disease in chimps caused by SIVcpz (Keele et al, 2009).

CONCLUSION

Thorough understanding of diseases transmission dynamics helps to forecast when and how we can control diseases by employing the existing preventive measures. These efforts have helped conserving the free ranging chimpanzee from 2002 to date. However natural deaths due to senescence, injuries, intraspecific aggression, maternal disability and orphaning are still encountered. The effect of SIVcpz in Gombe chimpanzee cannot be underestimated. Health monitoring of chimps in Gombe is important in understanding the epidemiology of diseases in free ranging chimpanzee in their natural environment.

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THE ETIOLOGY OF GIRAFFE EAR DISEASE (GED) IN MIKUMI - SELOUS ECOSYSTEM

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ABSTRACT
The present study had an objective of establishing the etiology of an ear disease of giraffes in Mikumi – Selous ecosystem. A total of 31 giraffes were randomly selected and immobilized for sample collection. Microbiological, parasitological, skin biopsies and skin scrapings samples were collected from the concave and convex sides of the pinna. Results showed that bacterial species such as Pseudomonas aer uginosa,Staphylococcus aureus,Bacillus firmus, Escherichia coli, Citrobacterfreundi and fungi species Blastomycetes dermatitis were present in ears of sick giraffes. Histologically, 20 (64.52%) of biopsies from GED had epidermalnematode larvae and interepidermal necrosis. Molecular biological investigation concluded that the nematodes were Spiriruids. I concluded that GED is a dermatitis caused by Spiriruidnematodes and the bacteria acted as a perpetuating factor.

INTRODUCTION
Since 1999 the Mikumi giraffes (Giraffacamelopardalis) were affected by an emergency of an unusual disease that affects their ears (pinna). Affected giraffes exhibited pendulous ears (hanging down instead of the normal upward pointing position) (Fig.2a). Also the pinnae were swollen and necrotic (Fig.2b). Among the first suspects in the causation of this emerging disease of the giraffe was Rhabditisbovis an etiological agent for Bovine parasitic otitis, a disease of cattle reported in neighboring Mkata ranch and Pastoral villages surrounding the park (Msollaet al., 1993).The linkage of the disease in cattle to the new disease of giraffes was based on the fact that they are both Bovidaeand therefore may be affected by similar or related diseases. Furthermore there exists a porous wildlife-livestock interface between the park and surrounding pastoral communities as well as with Mkata ranch (MINAPA, 2009). Under these circumstances there is a favorable environment for cross-border transmission of diseases between wild animals and livestock (Wambwa, 2002).

Also this strange disease in giraffes was seen, just after the heavy El Nino rains of 1997/1998 (Chester, 1999). Such drastic climate changes are known to have far reaching consequences on the health and survival of all forms of lifewhich could lead to mutations

and emergence of new micro-organisms and parasites (Jonathan et al., 2000). Furthermore the population of external parasites and insects is also poised to increase in the aftermath of above average rains (Kagarukiet al., 2003, 2005). It was also feared that the disease could possibly be zoonotic. Also it was necessary for Tanzania's giraffe not to be on the list of endangered species. Moreover West African giraffe (Nigeria giraffe – G. c. peralta) have been reported by Fennessyet al. (2008) to have been listed by IUCN as an endangered species. There were no records of major wildlife disease problems in giraffes in Tanzania andit was confined to giraffes. Furthermore the wildlife industry was faced up with a unique problem seen for the first time.This development clearly alarmed conservation specialists alike because there were knowledge gaps requiring concrete studies of the disease to be carried out. In order to redress this problem it was imperative and justifiable to search for the etiology of this strange disease and possibly contain or eradicate it.

MATERIAL AND METHODS

Study area

The study was conducted between September 2007 and September 2010 in the Mikumi-Selous ecosystem includingMikumi National Park (MINAPA) and Matambwe in the North Western part of Selous Game Reserve. MINAPA is the 4th largest National Park in Tanzania, covers an area of 3,230 square kilometers. It lies between latitude 7°00' and 7°50'S, longitude 37°00' and 37°30'E (Ereckson, 2001).MINAPA shares one ecosystem with Selous Game Reserve (Keyyuet al., 2003; Kagaruki et al., 2003;Collettet al., 2007). Selous Game Reserve lies between 7°20' to 10°30'S, and 36°00' to38°40'E. MINAPA has a single wet season from December to May with annual rainfall from 650 to 950mm, the rest a dry season (Mikumi, 2000).To the north is a village inhabited by Maasaipastorists whose livestock share pastures and water points with wildlife (Figure 1).

Sample collection and processing

The population of giraffe in Mikumi is thought to be approximately 250 and a large part of this population was thought to be affected. In order to find out the etiology, 31 giraffes were immobilized using M99 as described by Michael et al. (2006). The ears of immobilized giraffes were visually examined and sterile cotton swabs applied into the concave side of the pinna of sick and non-sick immobilized giraffes for bacterial culture. Isolation and identification of bacteria were done in standard procedure as described by Monica (1984), Carter and Lema (1998), Barrow and Feltham (2004). Two sets of skin biopsies of an approximate size of 2cm by 2cm were taken from the concave and convex sides of the pinna.

One set was preserved with 10% formalin in sterile plastic bottles for histological examination as described by John and Alan (1990). The other set was further cut to pieces of approximately 1cm2 in size, washed in fresh water and incubated in physiological saline for 24 hours at room temperature (21-25^{o}C) as described by Solismaa et al. (2008). Molecular investigation was carried out on biopsies collected. Crude DNA preparations were obtained by proteinase-K treatment as described by Bandiet al. (1998). The cox1 and 12S rDNA gene amplification and sequences were respectively generated as described by Casiraghiet al. (2001, 2004). Molecular phylogenic reconstruction was done on to the obtained cox1 and 12S rDNA genes whereby the sequences where aligned with available sequences. The alignment generated was analyzed using distance matrix method by using neighbor joining as described by Tamura et al. (2007). Also phylogenic analysis was performed using MEGA 4.0 softwareprogrammeas described by Tamura et al. (2007). Skin scrapings for mite examination were collected and processed in standard procedure as described by Harumalet al. (2003).

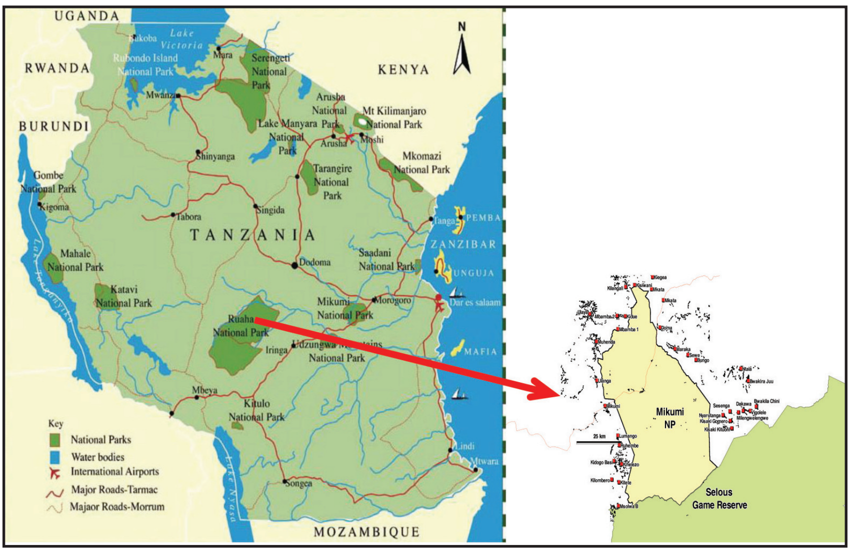


Figure 1: Map of Tanzania showing location of Mikumi – Selous ecosystem

Molecular biological findingsrevealed thatamplified and sequenced cox1 gene of the nematode had 650 base pairs long while the 12S gene had 450 base pairslong.Using the concatenated alignment of these genes, the Neighbor Joining Reconstruction generated a tree which showed that the nematode was a Spiriruidwhich lies betweenonchcercaandDirofilaria (Fig.3).

RESULTS

Pathogenic Pseudomonas aeruginosa, Staphylococcus aureus a normal skin flora, saprophytic bacteria Bacillus firmus, and fungi Blastomycetesdermatitidis were isolated.

A total of 22 samples from giraffes with GED revealed Pseudomonas aeruginosa, 17 Bacillus firmus, and 10 Staphylococcus aureus. Histologically, 20 (64.52%) biopsies from GED had epidermalnematode larvae and interepidermal necrosis (Fig.2c). Incubated skin biopsies from the concave side of affected pinna revealedthat most nematodes had 2.7mm to 4.3 mm long from head to tail (Fig. 2d).

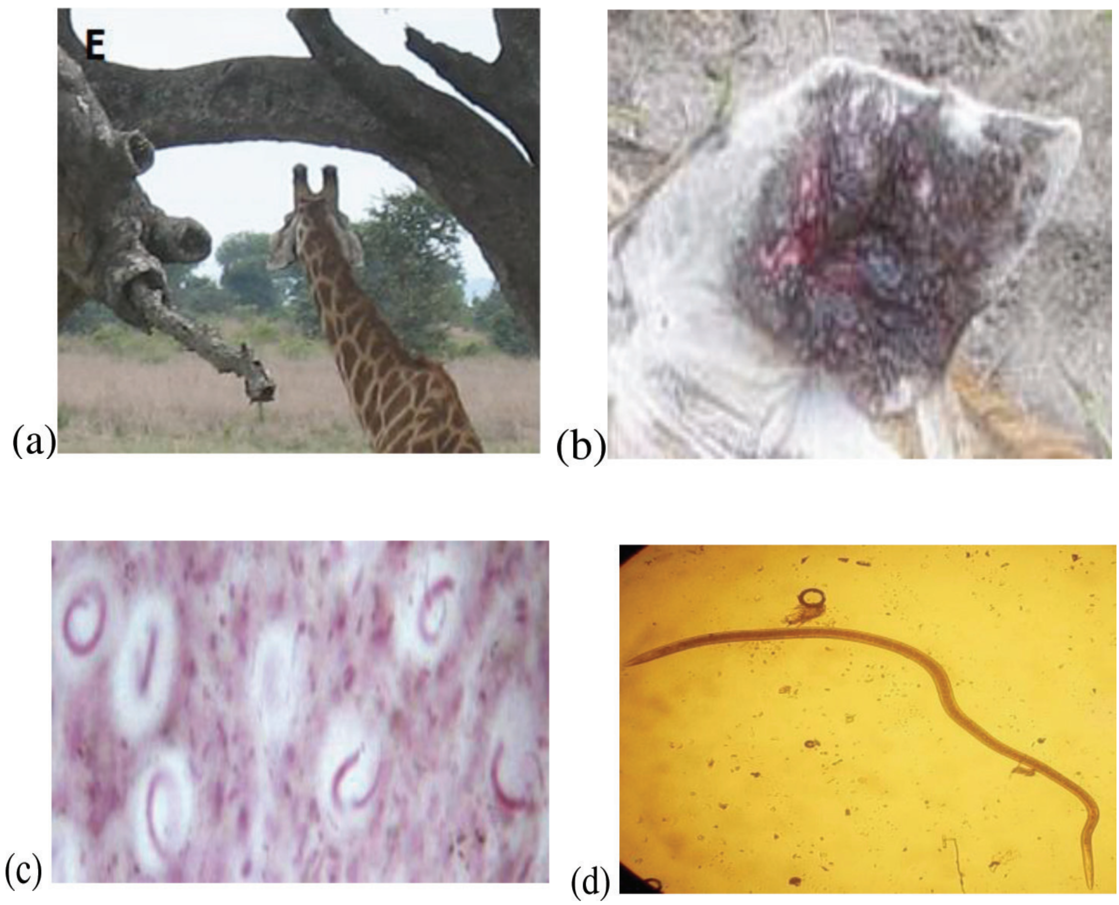
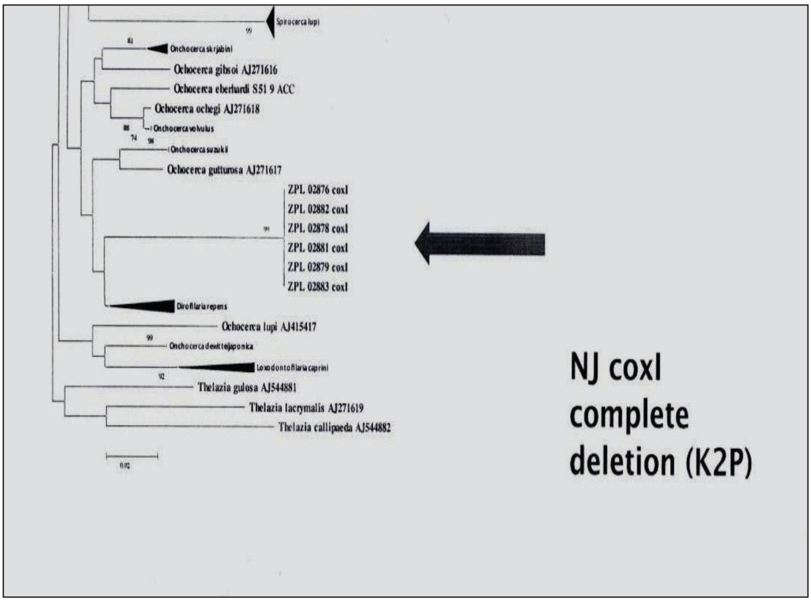


Figure 2: (a) Back side. Both pinnas pointing downwards(b) Severe case of GED(c) Histopathological section showing Spiriruid nematode larvae (d) An adult Spiruruid nematode isolated from pinna skin biopsies.



DISCUSSION

There had been a lack of information regarding to GED in the Mikumi – Selous ecosystem. Large number of giraffes had been affected and was probably a new disease since it had not been recorded in Tanzania (Mlengeyaet al., 2002; Kagarukiet al., 2003; 2005). The clinical and pathological features of this disease point to an inflammatory process targeting the skin covering the pinna on the concave part and sparing the external ear canal. Moreover giraffes showing GED are normally considered dermatological cases until otherwise proven (Kristensenet al., 1996). So the ear disease in giraffes is basically a dermatological problem. The disease starts with the epidermal layer of the skin and progresses to affect the dermis and may even destroy the cartilage as well as the convex part of the pinna. As it progresses it leads to sloughing off part or the entire pinna. It has been shown in the present study that there is a possibility in some seriously affected giraffes to undergo suppurative inflammatory process which extend to the subcutis and the underlying musculature (panniculus). This is an indication of a cellulitis, a reaction likely to lead to septicemia. These findings probably explains why a few cases become very sick, emaciated, and eventually die from a generalized disease problem emanating from involvement of vital organs such as the lungs (Mlengeyaet al., 2002). Different types of bacteria species and fungi from GED were isolated. The most significant ones were Pseudomonas aeruginosa, Staphylococcus aureus, Bacillus firmus, and fungiBlastomycetesdermatitidis. These bacteria and fungi are environmental inhabitants (such as soil, water, humans, animals, plants, sewage, decay materials of plant and animal) (Lederberg and Joshua, 2000;Cornelis, 2008).

The presence of these bacteria and fungi on wild animal diseases such as on GED could be as a results of changes in environmental factors caused by the then prolonged El Nino rains of 1997/98 (Chester, 1999). Since these are environmental bacteria and fungi, they could also be environmental contaminants on GED as previously suspected by Kagarukiet al. (2005). Histopathological investigation on skin biopsies from the concave side of the pinna revealed the presence of nematodes larvae in the dermis and epidermis of the skin of the pinna of giraffes affected with GED. Molecular biological identification confirmed the presence of spiruruid nematode. Spiriruidnematodes have been reported to infest domestic and wild animals through the skin (Kock and Kock, 1990; Wahl et al., 1994; Pampinglionet al., 2001; Solsmaa, et al., 2008). Also Solimaaet al. (2008) reported that Spiriruid nematodes usually inhabit the subcutaneous tissues, ligaments and aponeuroses of cattle and large mammals as predilection sites. Schmidt et al. (1982), Kock and Kock, (1990) and Anderson et al. (2000) reported that allfilarioid nematodes (Onchocercaspp, Parafilaria spp. and Stephanofilariaspp.) produce larvae into the skin. These nematodes cause parasitic infestations resulting in skin injury by penetration in to the skin. The affected skin develops necrotic dermatitis lesions as a result of Spiriruid nematode damage followed by secondary bacterial infection. This also explains why there was a recovery after experimental treatment of GED cases with antihelminthic (Ivomectin®) (Mlengeyaet al., 2002). It is concluded that GED is a dermatological problem caused bySpiriruidnematodes and bacteria working together, possibly in stressing states as caused by climatic changes.

CONCLUSION AND RECOMMENDATIONS

The research work has been able to conclude that GED is a dermatological problem. Spiriruidnematodes act as a primary cause whereas the bacteria are secondary. The severe GED is superimposed by bacteria and fungi working together, possibly in stressing states as caused by climatic changes. However, the mechanism by which the nematodes and bacteria cause the damage to the pinna as was observed in this work is of interest.

From the present study it is recommended that:

(i) GED be known as Giraffe Pinna Dermatitis
(ii) The mechanisms by which the nematodes cause theprimary pinna lesions needto be studied.
(iii) The role of arthropodsand other vectors in the transmission of the disease also need further study.
(iv) Establishment of a national nematode bank and reference archive with identification keys for future reference.
(v) There is a need for establishment of micro weather stations at strategic points in each ecozone for ecological and climate monitoring
(vi) Establish electronic geomaps for every national park in the country to assist in future development of early warning systems

(vii) Establish GED monitoring programme and treat the few remaining cases in the ecosystem

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FEASIBILITY STUDY OF TSETSE AND TSETSE BORNE DISEASES AT SELOUS GAME RESERVE AND OPTIONS FOR CONTROL

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ABSTRACT

Tsetse and tsetse borne diseases affecting humans are potential threat to tourism sector if the vector is not controlled. Tsetse flies transmit trypanosomes that cause sleeping sickness in human. Tsetse flies become infected with trypanosomes by feeding on infected hosts. Many wild mammals in tsetse endemic areas are infected with trypanosomes without themselves showing disease symptoms. They are reservoirs of the trypanosomes. Development of Trypanosomes to infective stages takes place in tsetse flies and are transmitted when an infected tsetse takes a blood meal on an uninfected host. A feasibility study of tsetse and trypanosomiasis challenges at Selous Game Reserve was carried out in December 2010. The objectives were to determine the dynamics, distribution and abundance of tsetse species found in the area, to collect tsetse samples for molecular characterization of trypanosomes circulating in the area and to advice the Selous Game Reserve management on suitable tools for controlling tsetse in the reserve. Four traps, (Biconical, Pyramidal, stationery and mobile Sticky panels (white)) baited with attractants were used for sampling.Trapped flies were emptied after 24hrs and sorted into respective species and sex and recorded accordingly. Results showed that Glossina m. morsitans 47% (193) and G. pallidipes 53% (218) were the species found in the area. Their distribution and abundance was vegetation dependant. 92% (378) were trapped in open wooded area with a composition of G. pallidipes 49.5% and G.m. morsitans 50.5%. Flies from bushy areas contributed 8% of which 31 were G. pallidipes and only two G.m. morsitans. Mobile Sticky panels caught more flies 92% (378) than stationery traps and panels which caught 8% (32) of the flies. Molecular characterization on 40 whole extracted tsetse's DNA indicated an infection rate of 5% and none were human infective trypanosomes. Results indicate that control strategies should be concentrated on open woodlands where tsetse infestation is high and visibility of insecticide treated targets is also high for maximum control impact on the vector.

Key words: *Tsetse fly, trypanosomiasis traps, trypanosomes, and insecticide, vegetation types*

INTRODUCTION

Sleeping sickness or Human African Trypanosomiasis (HAT) is endemic in Sub Saharan Africa. Trypanosoma brucei rhodesiense occurs in East and southern Africa and is mainly transmitted to humans by tsetse flies of the Glossina morsitans group. The disease is zoonotic involving wild animals, livestock and humans. The disease is normally underreported as it occurs in rural areas where awareness is limited especially on transmission and symptoms in relation to other infection such as malaria and TB. Furthermore the disease tends to occur in form of epidemic outbursts. In Tanzania the disease is mostly common in western part (Kigoma, Rukwa and Tabora) and on the north western part of the country along the Serengeti Ecosystem. The disease is also exceptionally travel associated, and about 50 cases are reported yearly outside Africa (Gautret et al., 2009).

Tsetse flies apart from transmitting the disease, they are a nuisance to both park, game reserve staff, tour operators and tourists visiting tsetse infested areas. The Selous Game Reserve is one of the game reserves that suffer from high tsetse infestation which threaten tourism opportunities. However, there have been plans to control tsetse flies from some important tourist posts in the reserve. The reserve is located in the southern part of Tanzania and covers a total area of 54,000 km². The main part of the area that was targeted for control was along the Mivumo River Lodge and Selous Tented Lodge which is owned by Serena Hotels. The area is between Rufiji and Matombo districts and is transected by Rufiji River and other small rivers. Different kinds of wild animals are found in the area. The area is dominated by Miombo woodlands and other vegetation cover which include Acacia, Savanna grassland, bushy and wetland vegetations. The Miombo woodlands are normally the preferred habitat by the Morsitans group of tsetse flies (Leak, 1999).

Tsetse survey was first conducted in this area during the dry season in December 2010. The study was carried out in order to collect essential information on tsetse prior to the actual control program which included: Tsetse species and composition found in the area and trypanosome types circulating in the area. The collected information was needed in order to assist in designing a sustainable strategy against tsetse which apart from being the vectors of trypanosomiasis, they are a nuisance to tourists and other people visiting this area. Hence the main objectives of this study were as follows:-

1. To control tsetse flies found around the two lodges and areas where game viewing is operated
2. To monitor the impact of the control strategy on the population density of tsetse

MATERIALS AND METHODS

Phase I: Baseline data collection

Tsetse flies were sampled using four different types of traps namely Biconical (Challier & Laveissiere, 1973), Pyramidal (Gouteux & Lancien, 1986), stationery white Sticky panel (Vreysen at al., 2000) and mobile white Sticky panel (TTRI unpublished). Traps deployment was based on the vegetation cover, visibility of the traps and wild animals' activities such as grazing areas and watering points.

Collection of the tsetse flies trapped was carried out after 24hrs of trap deployment at the sites. Traps were baited with attractants namely acetone and sachet of phenols placed near the traps in order to improve traps catching efficiency. Caught flies were recorded accordingly in terms of numbers, species and sex. The mobile sticky panel was mounted on the back of the vehicle and tsetse catches were recorded and removed after every two kilometers interval. Geo-referencing of traps and trapping sites were carried out using GPS Map 76 (Garmin®) and the coordinates of trapping sites were recorded in the UTM projection.

Phase II: Actual control program

A total of 14 Large White plastic (PCV) panels, 14 Pyramidal traps, 50 Tyre cover, Acetone, Temo-ocid Glue and 10 liters of Glossinex, 300 Blue-Black-Blue (175cm x 50cm) targets of which some where horizontal and others vertical striped (Lindh et al., 2009) were used. These were dipped in a properly diluted insecticide (right/ recommended concentrations) and dried in the sun.

Control area:

The area was divided into three blocks - A, B and C basing on easy accessibility to the site for deploying target as follows:- Block A comprised the following sites; Mivumo River Lodge to Air strip through Selous Tented Lodge and Katambula. Block B: Involved the area from Mivumo River Lodge through Rhino project, old air strip, Presidential site, Boat house and Kidai. Block C: Comprised the game driving routes Mahogany loop, Paradise loop, Tembo route, Pofu route, Euphorbia route and view point. Control of tsetse flies in the three blocks was carried out using blue/black/blue insecticide-impregnated targets (ITTs). The targets were impregnated with Glossinex® 200 SC insecticide manufactured by EcoMed manufacturing (Pvt) Limited (Harare – Zimbabwe). A total of 300 ITTs were deployed in the three blocks (130 ITTs were deployed in Block A, 80 in Block B and 90 in Block C) along existing road tracks which acted as transects. Targets were deployment at 200–300 apart depending on vegetation cover, tsetse habitats and watering points; and 100 meters away from the road used by tourists. A total of 14 monitoring traps were also deployed in the control areas for monitoring the impact of insecticide treated targets on fly population. Traps were emptied once per week.

Molecular characterization of trypanosomes circulating in the area:

DNA from whole flies from 40 tsetse flies were also extracted using a Qiagen Kit for trypanosome characterization as previously described (Ferreira et al., 2008) showing that trypanosomes can be analysed from DNA extracted from whole flies without dissection. Amplification using Phusion Taq (FinnEnzyme) for Internal transcribed spacer (ITS) amplification was carried out in a DNA thermal cycler (Applied Biosystem) in a final volume of 20µl reaction mixture containing 11.4µl distilled water, 4µl of 5x Phusion HF buffer (FinnEnzyme), 0.4µl 10mM dNTPs, 1µl for each Primer, 0.2ul Phusion DNA polymerase and 2µl DNA template except for screening the presence of serum associate (SRA) gene (Gibson et al., 2002), where 4 µl of template was used. The polymerase chain reaction (PCR) condition involved an initial denaturation step at 98°C for 30 seconds, followed by 30 cycles of 98°C for 30s, 60°C for 40s, 72°C for 30s with a final elongation step at 72°C for 5min. 5µl of PCR product was mixed with standard loading dye (Hyperladder) and electrophoresed in 1.5% agarose gel, stained with ethidium bromide (5µg/ml) and the product visualized and photographed under ultraviolet illumination. A positive control (with reference genomic DNA) and negative control (without DNA, only with distilled water) were included in each set of reactions.

RESULTS

i. Pre – control phase

Vegetation in the study site was found to be open woodlands, mivumo woodland with bushy to thick vegetation, typical of savannah type of vegetation. Tsetse survey results indicated that the area is infested with two species of tsetse namely G. m. morsitans and G. pallidipes. The species composition was 53% for G. pallidipes and 47% for G. morsitans. The apparent density (AD) was 25.6 (tsetse / trap / day) (Table 1). Tsetse responses to trapping tools are presented in Table 2a & 2b and tsetse distribution and abundance per vegetations in Table 3. Table 4 shows the proportion of tsetse species per vegetation types.

Table 1: Tsetse apparent density and species composition during the dry season of Dec 2010

Tsetse species	Female	Male	Total
Glossina pallidipes	45	173	218 (53%)
G. m. morsitans	32	161	193 (47%)
Total	77	334	411
Apparent density (Tsetse/trap/day)			411/4/4 =25.6

Table 2a: Tsetse catches per trapping tools

Trap type	*G. pallidipes*	*G. m.morsitans*	Total
Mobile	**165**	**186**	**351** (85.4%)
Stationary traps	**53**	**7**	**60** (14.6%)
Total	218	193	411

Table 3. Tsetse catches per site

Site	Vegetation	Trapping device	*Gp*	*Gmm*	Total	% of total catches
Selous	Open woodland	Mobile sticky panel	87	68	155	38
Mto Ndorobo	Mivumo/open woodland	Stationary trap	0	0	0	0
Malala 2km	Open woodland	Mobile stick panel	96	58	154	37.5
Direction to Rhino project	Bushed	Stationary panel	14	2	16	3.9
Rhino Project	Bushed	Stationary trap	17	0	17	4.1
Mahogan loop	Open woodland	Mobile sticky panel	2	22	24	5.8
Paradise loop	Open woodland	Mobile sticky panel	2	18	20	4.9
Euphobia	Open woodland	Mobile sticky panel	0	18	18	4.4
View point	Open woodland	Mobile sticky panel	0	7	7	1.7

ii. Control phase

Table 5 below shows catches of tsetse flies collected during monitoring phase after deployment of 300 IITs in different areas earmarked for tsetse control. The tsetse density declined to 1.69 compared to the apparent density (AD) before the deployment of the ITTs which was 25.6.

Table 4: Tsetse species per vegetation types

Traps	MTI	MT2	MT3	MT4	MT5	MT6	MT7	MT8	Total & Apparent Density
Number of tsetse	14	28	111	144	56	74	39	208	674/50days/8traps = 1.69

iii. Trypanosomes circulating in the area

From the extracted tsetse DNA, only two flies (2/40) were infected with trypanosomes, one with T. vivax and the other with T. congolense and no human infective trypanosomes were recorded. However more samples need to be analysed from Selous to substantiate this.

DISCUSSION

The study area is infested with two species of tsetse fly namely G. m. morsitans and G. pallidipes, from the Morsitans group. These are normally reluctant to enter stationary traps and tend to swarm towards moving objects (Vale, 1974; Hargrove, 1991). Hence a decision was made to control the vectors by blue black ITTs which were hanged on trees to allow free movement and swinging to attract tsetse. To enhance control, the use of various other means were incorporated where by all vehicles were sprayed by synthetic pyrethroids (Glossinex) especially the lower bodies of vehicles and tyres; ITTs were deployed near lodges and other frequently visited sites by tourists, game rangers and park staff.

Within 50 days of ITTs deployment; a decline in tsetse populations was recorded from 25.6 to 1.69 ADs. The apparent density before initiating the control was not very high compared to flies seen visiting most traps. This could be due to the reluctance of most Morsitans tsetse to enter into stationary traps. Observation made by Shaw et al (2007) on G. pallidipes and G. morsitans indicated that only 47 – 30% of tsetse approaching a trap landed on it or entered it, which means that about 53 – 70% of tsetse visiting the trap did not contact it. This is the phenomenon that was also noticed in Selous. Flies would land on traps without entering the retaining cage and this is the reason of including sticky panels which tend to capture all flies which will land on the panels.

The decision to include both vertical and horizontal oblongs was due to the fact that both are equally attractive for G. m. morsitans and G. pallidipes, (Lindh et al., 2009), but also the horizontal oblongs are more attractive to the two species (Torr, 1994).

None of the extracted and analysed tsetse DNA contained human infective trypanosomes but only T. vivax and T. congolense were recorded. The results are similar to recent findings which were obtained from 82 whole DNA extracted from tsetse trapped from Rufiji district which is an area adjacent to Selous Game Reserve. None of these samples also revealed human infective trypanosomes (Malele et al., 2011). However more samples need to be analyzed from Selous to substantiate this. Although the present results indicate that the foci is still silent, vigilant control measure of the vector need to be stepped up in order to continue keeping the foci silent. Southern Tanzania (Nachingwea, Lindi Kilwa) is a silent foci of sleeping sickness, the last case of HAT was detected in 1974 (Temu, 1979).

ITTs are important tools for controlling tsetse if properly treated with a correct amount of insecticide as recommended and deployed accordingly.

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EPIDEMIOLOGY OF SCHISTOSOMA MANSONI IN HUMANS AND NON-HUMAN PRIMATES IN THE GOMBE ECOSYSTEM, TANZANIA

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ABSTRACT

Increased contacts between humans and wildlife around Gombe National Park in western Tanzania have raised the risks of disease sharing among them. Although both humans and non-human primates in the area have been diagnosed with schistosomiasis, it is not known whether schistosome strains infecting them are epidemiologically and genetically distinct. The genetic ecology of Biomphalaria snails, the intermediate hosts for schistosome parasites in the area is also not well known. This study investigated the patterns of schistosomiasis infection in humans and non-human primates in Gombe and surrounding villages. It also determined the genetic mixing-up of snails in streams and assessed whether they can spread schistosomiasis between villages. Snails were collected using a mesh wire scoop and exposed to light for shedding schistosome larvae. Faecal samples were obtained from 16 vervet monkeys and 100 baboons at Gombe and examined for schistosomes using the formol-ethyl acetate technique. Stool samples collected from 400 people were analysed for parasites using the Kato-Katz technique. Extra faecal samples from 41 people and 9 baboons infected with schistosomiasis were subjected to molecular analysis to characterize the genotypes of the schistosomes. Overall, the prevalence of Schistosoma mansoni in humans was 45.05% and 13.33% in baboons, and there was no infection found in vervets. Schistosome parasites from baboons and humans were confirmed to be S. mansoni using DNA analysis although their genetic relationship has not been established. None of the snails from Gombe and Bugamba had schistosome parasites while 22.64% from Mwamgongo, 22.58% in Kiziba and 16.62% from Kigoma town were infected. These findings indicate that the distribution of schistosomiassis in Tanzania is more widespread than earlier thought. They also confirm the ability of baboons in maintaining the persistence of schistosomiasis in nature. The implications of these observations to animal and public health in the Gombe area will be discussed.

Key words: *Biomphalaria, ecosystem, epidemiology, Gombe, schistosomiasis*

INTRODUCTION

Schistosomiasis is a human infectious disease caused by trematode parasites of the genus Schistosoma, of which the most important species are S. mansoni and S. haematobium (Chitsulo et al., 2000). S. haematobium causes urinary schistosomiasis and occurs in Africa, the Middle East and parts of India while S. mansoni causes intestinal schistosomiasis and is widespread in Africa, the Middle East, South America and the Caribbean (WHO, 1985). Equally important is S. japonicum, which also causes intestinal schistosomiasis and is predominantly found in China, the Philippines and some parts of Indonesia (WHO, 1985). Other less widespread species are S. mekongi found in Lao People's Democratic Republic, Cambodia and Thailand in the Mekong valley and S. intercalatum whose distribution is limited to West and Central Africa (Cheesbrough, 1998).

Schistosomiasis, also known as bilharzia, has an annual mortality rate of about 280,000 deaths (van der Werf et al., 2003) with about 780 million people at risk of being infected with the disease (Chitsulo et al., 2000). It is a chronic disease causing potential damage to internal organs such as the liver, spleen and gall bladder as well as stunted growth and impaired cognitive abilities in children (McGarvey, 2000; King et al., 2005). Schistosomiasis affects many people in developing countries, yet the disease does not receive treatment and financial support compared to the three killer diseases of malaria, TB and HIV/AIDS (Hotez & Kamath, 2009). However, the impact of schistosomiasis is becoming more apparent as more people get infected and it is now considered second to malaria among parasitic diseases due to its effects on the socio-economic wellbeing of humankind (WHO, 1985).

Both S. mansoni and S. haematobium species are endemic throughout Tanzania (Brooker et al. 2009). S. mansoni infection is widespread around Lake Victoria area and northeast parts of the country. In contrast, S. haematobium infection is distributed along coast of the Indian Ocean as well as in areas around Lake Victoria (Fig. 1). Estimates in 1977 indicated that 19% of the Tanzanian population was at the risk of acquiring schistosomiasis, but exposure risks and prevalence of the disease and snail vectors have been increasing (Rugemalila, 1991). Hospital records show that intestinal schistosomiasis may be common in humans at Gombe and in the neighbouring villages of Mwamgongo, Bugamba, Kiziba and Mtanga (Mung'ong'o, 1999; Bakuza & Nkwengulila, 2008). However, no systematic study has been conducted to establish the infection patterns of schistosomiasis in the area. This study produces useful information on the baseline data on schistosomiasis in the Gombe area. In Gombe National Park, schistosomiasis was first reported in humans in 1983 (Muller-Graf et al., 1997), in one baboon in 1989 (Murray et al., 2000) and in two chimpanzees in 1991 (Nutter, 1993). Muller-Graf et al. (1997) observed higher prevalence of S. mansoni in baboon groups with the most human interactions. These baboons spent most of their time around residential areas in the park and would often enter houses in search of food (Muller-Graf et al., 1997; Murray et al., 2000). This has raised concern over the possible source and spread of schistosomiasis in the park. The disease may have been introduced into Gombe by research and park staff who spend their annual holidays in other schistosome-endemic areas in Tanzania (Muller-Graf et al., 1997). It may also have originated from the people who were staying in the area before it was designated a National Park in 1960, following which all conventional human settlement was banned (Goodall, 1986). Elsewhere, field studies have shown that baboons are capable of maintaining schistosome infection in the absence of humans and that they can also transmit it to humans (Zahed et al., 1996). Zahed et al. (1996) reported that S. mansoni in Hamadryas baboons Papio hamadryas in Saudi Arabia could be highly infective to humans.

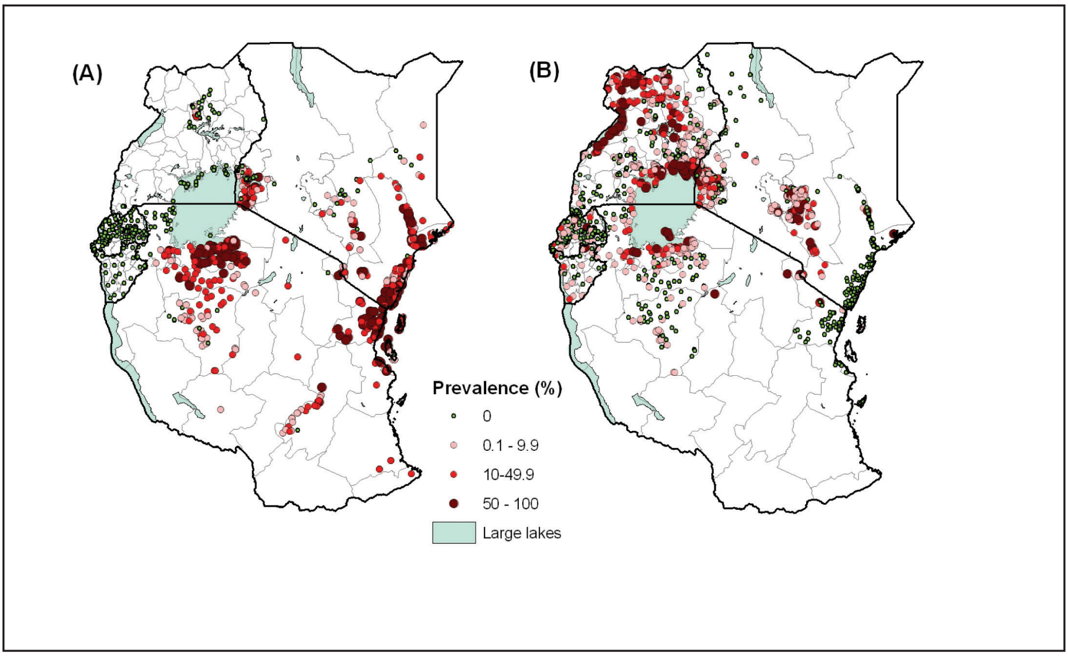

Fig. 1: Geographical distribution of schistosomiasis in East Africa: (A) Schistosoma haematobium and (B) S. mansoni (Brooker et al. 2009).

However, the genetic relationships among the population(s) of S. mansoni in humans and baboons sharing the same habitat in the wild environment have not been established. It is unclear for instance, to what extent baboons and vervets in Gombe could possibly serve as a potential reservoir for human schistosomiasis. This study was initiated to address these questions and to assess the epidemiological implications of schistosomiasis infection in baboons in the Gombe area. The study was also proposed to explore and understand the ecology of Biomphalaria snails, the intermediate hosts for S. mansoni.

Studies on snails, the intermediate hosts for schistosomiasis have indicated that transmission of the diseases only takes place in areas where these hosts are present and people come in contact with infested water (Appleton, 1978). Hence, knowledge of snail distribution and habitat preference is a prerequisite for understanding the epidemiology and control of schistosomiasis (Utzinger & Tanner, 2000). Previous studies at Gombe have not established the transmission foci for schistosomiasis, although snails are thought to occur in inland marshes in the park (Muller-Graf et al., 1997; Murray et al., 2000). During the present study snails were collected from valleys in and outside Gombe National Park.

STUDY OBJECTIVES

The main objective of this study was to determine the population genetic structure and variation of S. mansoni parasites and establish the possibility of cross transmission of schistosomiasis between humans and non-human primates in the Gombe area. The study had the following specific objectives: (1) Determine infection levels of schistosomiasis in humans and non-human primates, (2) Characterize the genetic structure of human and baboon schistosome strains and determine gene flow levels among schistosome strains from different host species, (3) Determine prevalence and diversity of other parasites in non-human primates at Gombe National Park; and (4) Assess the prevalence of schistosomes in intermediate hosts (snails)

MATERIALS AND METHODS

Study area

This study was conducted in Gombe National Park and the neighbouring villages (Fig. 1). More details on Gombe National Park are provided in Goodall (1986) while the villages are described in Mung'ong'o (1999), Lwoga (1997) and Lombardozzi (2003).

Study animals in Gombe National Park

In addition to humans, this study investigated the levels of schistosomiasis in non-human primates from Gombe National Park including baboons (Papio anubis) and vervet monkeys (Cercopithecus aethiops). Baboons live mainly in the forested area of the park, although their home ranges extend to the shores of Lake Tanganyika and to the research camp where park and research staff and their families live. The vervets and some groups of baboons live on the park boundaries, and often raid human settlements and farms outside the park (Goodall, 1986).

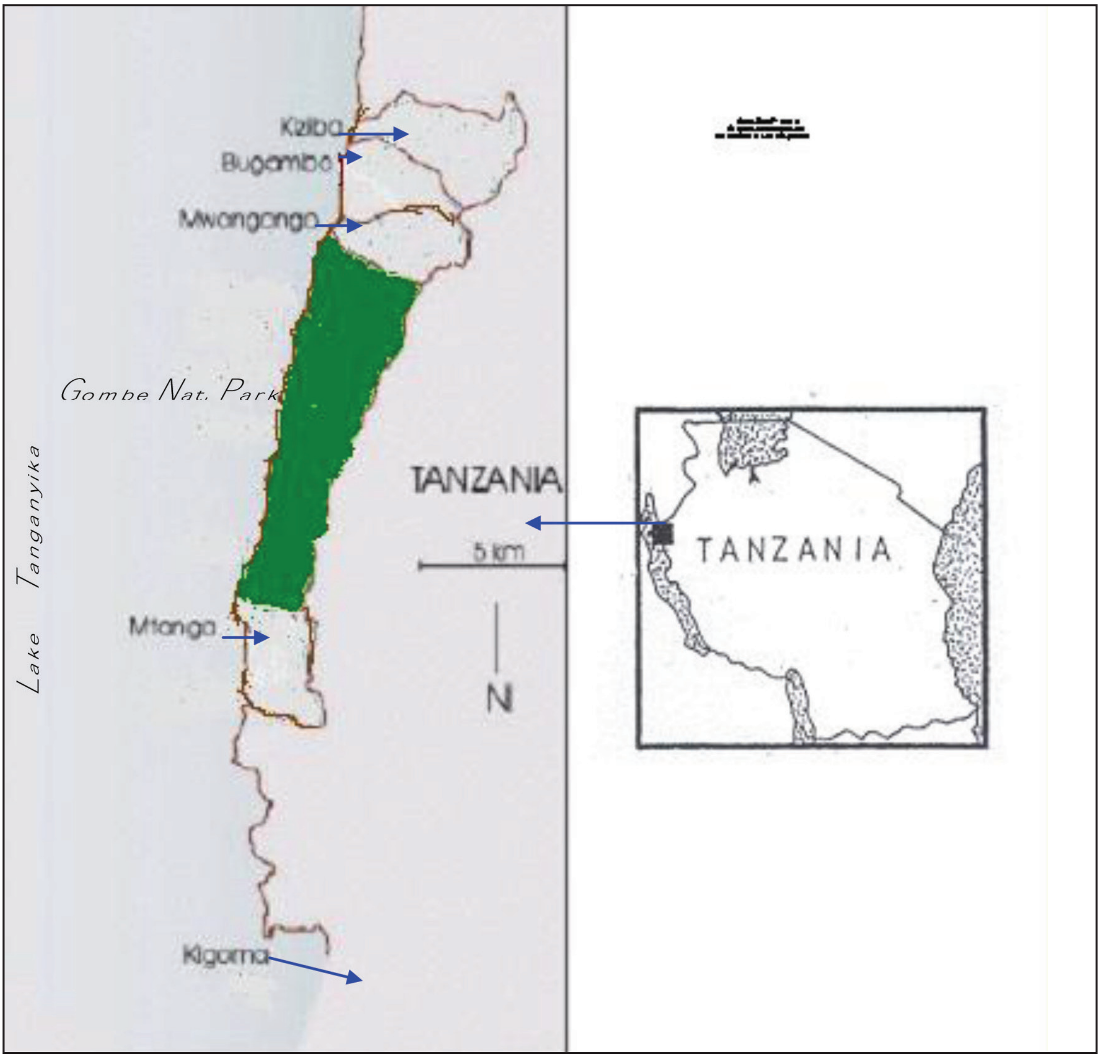

Fig. 2: Study area with the arrows showing (from bottom to top) Kigoma town, Mtanga village, Gombe National Park (highlighted area) and Mwamgongo, Bugamba and Kiziba villages, respectively, (Source: Lombardozzi, 2003)

Ethical considerations

Ethical Clearance (No. NIMR/HQ/R.8a/Vol.IX/892) used during this study was issued by the Tanzania's National Institute for Medical Research (NIMR). Faecal samples were collected from human and non-human primate individuals following standard guidelines and procedures (WHO, 1991; Cheesbrough, 1998). Before collecting the samples, a meeting was held with the health and school personnel and village leaders to discuss the objectives of the study and its benefits to the communities involved. The village executive officers (VEOs) then informed people in their respective villages about the survey asking them to volunteer in the exercise. An informed consent was obtained from the people before beginning data collection. They were asked whether they or their children should participate in the study. Praziquantel drugs were provided to infected individuals.

Collection and microscopical examination of human stool

Materials for collecting stool samples were distributed to each participant and instructions given on the collection protocol. The materials included a wooden spatula for picking up stool, a plastic vial (120 ml) for depositing the stool and a polythene plastic bag for carrying the samples. The vials were labeled with the provider's name, village locality and collection date. Additional information such as age, sex, occupation, weight, health status and time spent in the area were recorded on a questionnaire. Sampling materials were distributed in the morning of day one and collected in the morning of the following day. In the laboratory, stool was examined for S. mansoni and other helminths using the Kato-Katz protocol (Ebrahim et al., 1997; WHO, 1991).

Collection and microscopical examination of animal stool

Stool was collected from 110 individual baboons in Gombe National Park and 26 vervet monkeys. Except for those living at the park boundary, these baboons are habituated to human presence, and are individually recognized, making it possible to obtain independent samples. The baboons were followed as they foraged and stool picked up from the ground immediately after defaecation and preserved in 10% formalin. Samples from unhabituated baboons and vervets were collected by visiting their sleeping sites at dawn. As they left their nests, they defecated and each separate stool was picked up and preserved in 10% formalin. The samples were examined for schistosomes and other parasites using the formol-ethyl acetate technique (Cheesbrough, 1998).

Collection of faecal samples for DNA extraction

Additional faecal samples were collected and preserved in RNA-later for DNA extraction. The samples were obtained from individuals who had high numbers of schistosome eggs during the initial sampling (both humans and baboons).

The samples were processed to isolate schistosome eggs, as described by Steinauer et al. (2008). The protocol involved mixing the faecal samples with filtered stream water. The homogenate was then passed through a series of sieves of different sizes (800, 212 and 38µm) to remove large debris. The filtrate on the bottom sieve (38µm) was washed into a 15ml centrifuge tube and centrifuged three times with distilled water to clean the samples. Pellets from each sample were then preserved in 15ml centrifuge vials containing approximately 2ml RNA-later solution (QIAGEN GmbH, D-40724, Hilden, Germany) and kept at room temperature.

DNA analysis of human and baboon faecal egg samples

DNA extraction procedures for human and baboon faecal schistosome eggs followed Qiagen kits. PCR amplification and sequencing of the small subunit rRNA region of the DNA was performed to confirm the identities of S. mansoni species.

Snail collection

Snail sampling followed the protocol described in Madsen (1995). Initially, the study area was surveyed to identify sampling sites in each village. Sampling sites were selected along a major stream in each village by pacing out the length of the river, with each site being located at least 200m apart. A total of 12 sites were selected and sampled along each stream with 6 of them being located outside the village residential areas. Snails were then systematically searched for in each site for a period of 15 minutes using a scoop (30 by 30 cm) covered with a 2x2 mm size mesh wire. Snail sampling for each site was conducted fortnightly and additional information such as air temperature, water temperature, pH and flow rate were recorded on each visit. Where water prevented the use of scoops, snails were picked by hand using a pair of long forceps (Ouma et al., 1989). To maintain consistency, the same person (J. Bakuza) searched for the snails throughout the study period.

Shedding of parasite larvae (cercaria) from snails

In the laboratory, snails were experimentally treated to enable them to shed cercaria larvae following Wolmarans et al. (2002), with slight modifications. Each snail was washed separately using distilled water and exposed to light (60w) for 6 to 12 hours and observed under a dissecting microscope every four hours. Observed schistosome larvae were picked up using a glass Pasteur pipette and preserved in RNA-later. All snails were then dissected and their tissues preserved in RNA-later solution until needed for DNA extraction. Snail DNA was tested for the presence of schistosomes as described elsewhere (Melo et al., 2006).

RESULTS

Parasite prevalence and intensity

On average, the prevalence of S. mansoni was 45% in humans and 11.24 % in baboons, with no infection in vervets. Children tended to show higher intensity of infections than adults, schistosomiasis infection varied between villages (Figs. 3 & 4). Other parasites diagnosed in humans included Trichuris trichiura (1.49%), Ascaris lumbricoides (0.99%), and Taenia sp. (0.25%).

Molecular analysis of human and baboon faecal eggs

Sequencing of the small subunit rRNA region of human and baboon faecal eggs confirmed the parasites to be S. mansoni.

Snail survey

Based on experimentally induced shedding, none of the snails from Gombe and Bugamba had schistosome parasites, while 22.64% from Mwamgongo, 22.58% in Kiziba and 16.62% from Kigoma were infected.

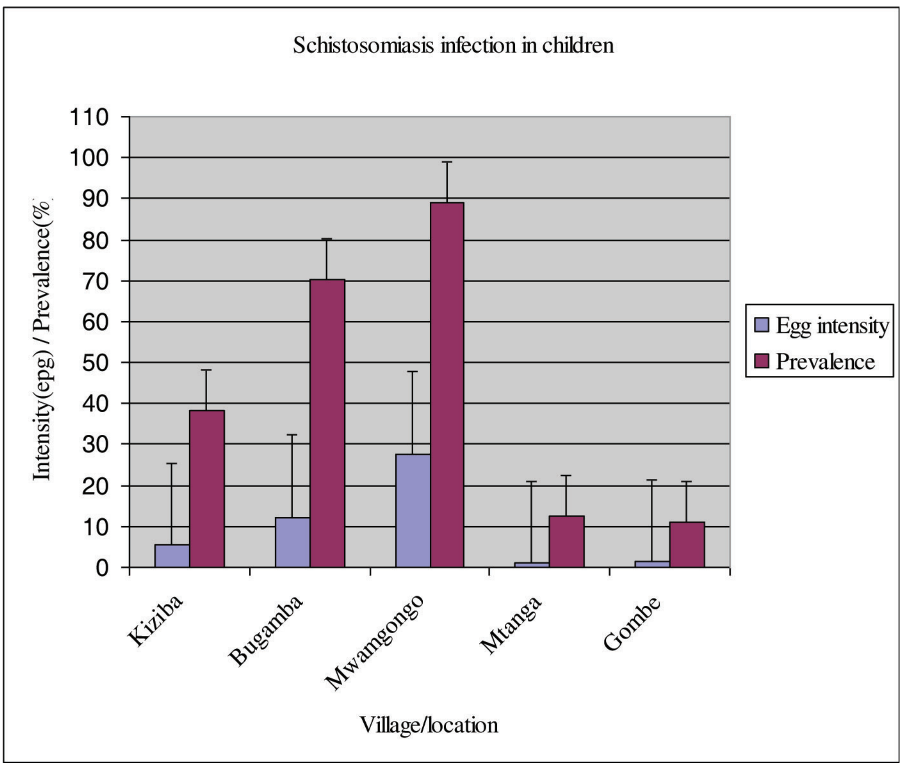

Fig. 3: Variation of schistosomiasis infection in children across villages

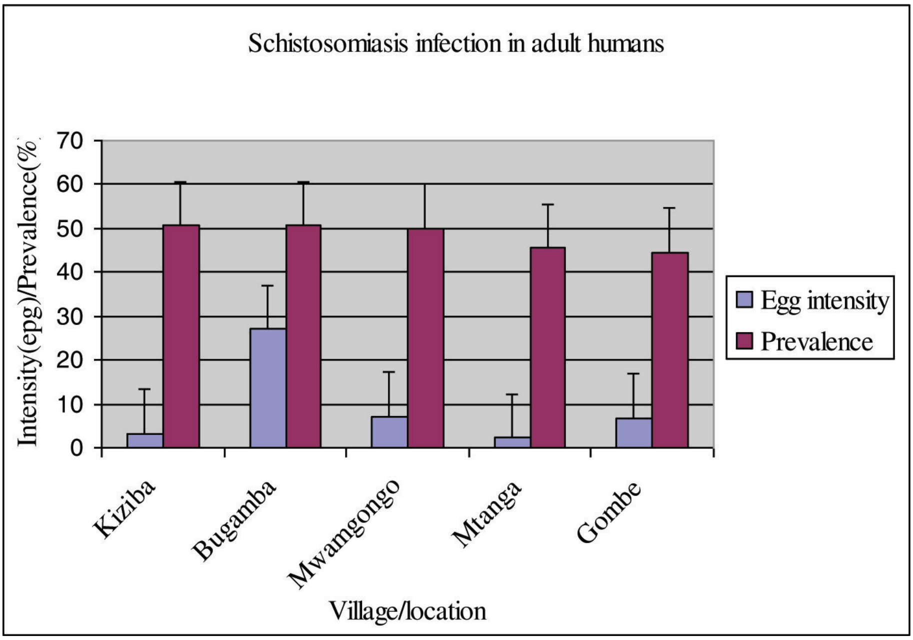

Fig. 4: Schistosomiasis infection in adults across villages

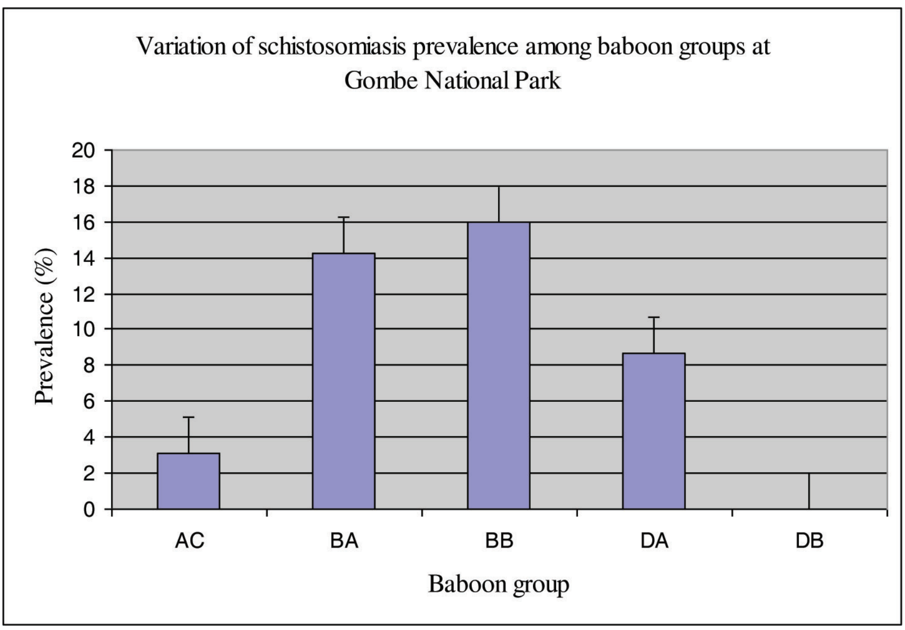

Fig. 5: Variation in schistosomiasis prevalence among baboon groups at Gombe National Park

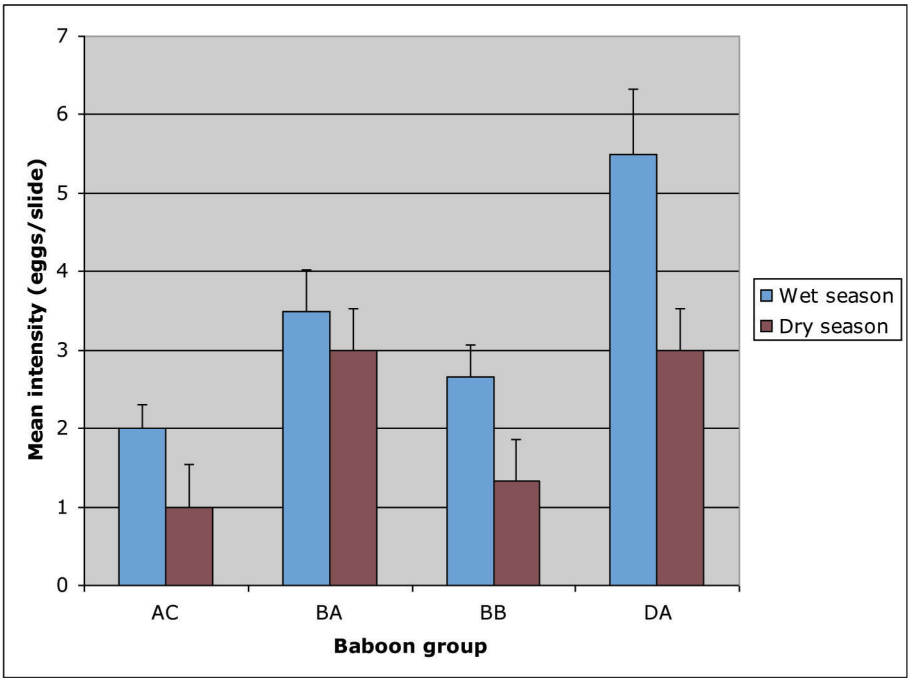

Fig. 5: Seasonal variation in schistosomiasis intensity among baboons at Gombe National Park

DISCUSSION

These preliminary findings suggest that the distribution of intestinal schistosomiasis in Tanzania is more widespread than was thought previously. This part of the country was earlier regarded as either a disease free or low infection area (Brooker et al., 2009). Both prevalence and intensity of schistosomiasis were particularly higher in school-age children than in adults, although the differences were not significant. The higher levels of infection recorded in this area are a typical scenario for any schistosome endemic area (Rugemalila, 1991; de Vlas, 1996). The area is close to the Rusizi plain in Burundi where similar prevalences of schistosomiasis infection have been reported (Gryseels, 1991). The movements of people between the two areas may have facilitated the spread of the disease at equal rates.

The diagnosis of schistosome eggs in baboons indicates the ability of these animals to maintain the life cycle of intestinal schistosomiasis in nature. Since the causative agent (S. mansoni) of schistosomiasis was found in both humans and animals, this may also be a further confirmation of the zoonotic nature of schistosomiasis. Such observation or indeed any cross transmission of S. mansoni between humans and animals, is a potential threat to conservation and human health in the park.

Based on the present results and those from previous surveys, it may be stated that some sharing of schistosomiasis between humans and baboons at Gombe could happen given the high rates of interaction between them. Baboons and humans in the park use the same habitat and other resources such as the forests, swamps and water bodies, some of which also harbour snails. Further molecular analyses (microsatellite analysis) will be required to assess whether the same genotypes are shared between humans and baboons and assess its implication to animal and public health in the area.

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REPRODUCTIVE DISEASE OF OLIVE BABOONS (PAPIO ANUBIS) OF GOMBE NATIONAL PARK: OUTBREAK, TIME-COURSE, AND ATTEMPTS TO LIMIT RECURRENCE

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ABSTRACT
In 1988, an infection appeared in one of the habituated study-groups of olive baboons in Gombe National Park. The observable signs were lesions on the genital tissues of both sexes. Susceptible individuals were all sexually active baboons, that is, any male above infancy, and any adolescent or adult female. In some individuals these signs worsened progressively, in a few cases until death, while in other individuals they disappeared then reappeared periodically. Because adult males transfer between groups, the infection was transmitted from C Group to D Group and then to A Group. Initial tissue-diagnosis suggested the spirochaete Treponema. In an attempt to prevent transfer to the endangered chimpanzee population (via play between juveniles), treatment was initiated, at first by immobilisation and injection, later by administering Penicillins in banana, to all sexually active group members. Results of treatment were usually good, but repeat oral treatments had to be given to various groups in subsequent years, either when the signs recurred or more often when an infected adult male joined the group from outside. In recent years the disease has not reappeared in any of the six study groups, but treatment is sometimes called-for in some of the un-habituated groups living in the north of the Park. Details will be given of usual the time-course and spread of the infection between individuals within groups. The nature of the infection, between Treponema and Herpes, will be evaluated. The cause of the outbreaks will also be discussed in comparison with a similar infection more recently documented in the baboons of Lake Manyara National Park.

INTRODUCTION
Olive baboons (Papio anubis) have been studied at Gombe since 1967, but illnesses have affected only small numbers at a time, so that there were never any large-scale outbreaks of disease (in contrast to the pattern among chimpanzees, Williams et al 2008: cf subsequently Bakuza, 2012). However, in 1988, a new illness appeared in one group, which quickly spread. This was, a disease of the genitals, and while it has become quite well-known since, almost nothing has yet been published, except briefly (Wallis & Lee, 1999; Wallis & Collins, 2004), and a mention in a TAWIRI Conference 2003 (Fyumagwa et al 2003).

Here we describe the first outbreak of this disease, its initial spread, our attempts to contain it, and its possible cause. We focus on management aspects because of the parallel appearance of a very similar disease in the baboons at Lake Manyara (Mlengeya, 2004), where disease-management has also been discussed.

METHODS

Baboon Groups and Observers.

Observations were made by eight different field assistants, each familiar with two or more habituated groups. They kept records of demographic and reproductive changes 4-5 days each week, and also monitored observable illnesses, including this one. Every group's individuals were recognised and named, and for many of them the matrilineal relationships were also known.

The study of this disease has relied also on four main veterinarians: initially Dr Kenneth Pack, consultant with Jane Goodall Institute in Congo Brazzaville, in 1988-89, approved by the then Director General of TANAPA. Secondly Prof. Peter Gray, University of Witwatersrand, approved for intervention in October 1998.
Thirdly Dr Magdalena Lukasik, (Gombe Veterinary Project 2001), and Dr Harald Wiik from TAWIRI. Also in 2003 came Dr Titus Mlengeya and Dr Morris Kilewo, of TANAPA Veterinary Department (Mlengeya, 2002), and more recent updates have been made by Dr Jane Rafael the veterinarian of Gombe National Park.

RESULTS

Onset and spread of the disease

There were five habituated groups at the start of this disease, but during its course they divided several times, such that at one point (1999) there were eleven groups under study, totalling 320 individuals. Fortunately the disease did not reach into all these groups. The condition was first recognised in C-Group in June 1988, although in retrospect we realise it was possibly first seen in one adult female a year earlier. Then in July 1988 a young adult male transferred from C into D-Group: in February 1989 he developed signs of disease, and in March two females were affected, thereafter spread through the group was rapid. Then in August 1989 another adult male moved from C to A-Group, he had no visible sign of infection (but could have carried it), and he was followed in October by another adult male, who was already infected. Two females and the first male started to show signs in November 1989.

Table 1: Prevalence of Infection in each Age-Sex class at start of first Treatment Dec. 1989: Prevalence as Percent, Number of baboons in bottom right. Duration of Outbreak is number of months since first detected.

Group & Duration	Males adult	Males immature	Females adult	Females immature	Percent, & N baboons
C-Group 19th month	33 % 9	30 % 10	83 % 18	0 % 6	49 % 43
D-Group 14th month	75 % 12	65 % 17	80 % 20	0 % 9	62 % 58
A-Group 4th month	20 % 10	0 % 20	11 % 18	0 % 12	7 % 60
Percent & N baboons	45 % 31	30 % 47	60 % 56	0 % 27	38 % 161

Table 2: Time-course of onset of disease in the adult females of C Group, from May 1988 to Dec 1989

	1988								1989											
C	05	06	07	08	09	10	11	12	01	02	03	04	05	06	07	08	09	10	11	12
Nm																				
MI	c	c	c	c	c	c	c	f	f	c	C	C	f	f	C	F	C	C	C	C
JU	c	c	c	c	c	c	c	c	c	c	**C**	c	c	C	c	c	c	c	C	C
PE	n	N	N	N	c	c	c	c	c	c	**C**	c	c	c	c	p	p	P	P	P
AL	c	c	c	?c	?c	c	c	f	f	f	?F	?F	F	F	F	F	F	F	F	F
PF	p	p	p	p	B	n	n	n	n	n	N	N	N	N	N	N	N	N	F	D
AN	c	p	p	?p	p	P	P	B	N	N	N	N	N	N	N	N	N	N	D	
PO	p	p	p	n	n	n	n	n	n	n	**N**	c	c	C	C	C	C	C	C	C
MD	p	p	p	p	p	b	n	n	n	n	**N**	N	C	P	P	P	P	P	B	N
PL	c	c	c	c	c	c	f	c	c	c	**C**	c	c	c	c	c	c	c	c	c
JT	c	c	c	c	c	c	p	p	p	p	**P**	B	N	N	N	N	N	N	N	N
FT	n	n	n	n	c	c	c	c	c	c	**C**	c	C	C	C	C	C	C	C	C
LN	c	c	c	c	c	c	c	p	p	p	**P**	B	N	n	N	N	N	N	N	N
FY	c	c	c	c	c	c	c	p	p	p	P	P	b	N	N	N	N	N	N	N
PH	c	c	c	c	c	c	c	c	c	c	**C**	c	c	P	P	P	P	B	N	N
MN	c	c	c	c	c	c	c	c	c	c	**C**	c	c	c	C	C	C	C	C	C
AE	c	c	c	c	c	c	c	c	c	p	**P**	p	p	p	b	c	c	c	C	C
AY								c	c	c	C	C	C	C	C	C	C	C	C	C
FR										c	**C**	c	c	c	c	c	c	c	c	c
PI													c	c	c	c	c	c	c	c

Key to Table 2: Females identified by names on the left, in order of age descending to youngest at the bottom. Months and years across the top. In each month is shown the female's health, upper-case bold means DISEASED, lower-case normal means apparently Healthy. Reproductive states: c and C – Cycling and mating, p and P – Pregnant, b and B gave Birth, n and N Nursing, f and F means Flat (reproductively quiescent), D means Died.

The distribution of prevalences in Table 1, and detailed examination of the time-course infection spreading through the individuals of each group each month, (of which Table 2 is an example) demonstrate four things:

1. The disease affected adult males, adult females, and young males (even as young as 1 year 3 months old): in other words, all sexually active members of the group.
2. While there was a tendency for females to show first signs when they were cycling and mating, (as expected if the pathogen was sexually transmitted), there was also another tendency for infections to become apparent in pregnancy especially near full-term, or in mothers who had recently given birth.
3. Signs of infection in any one baboon sometimes disappeared, but then reappeared a month or two later, implying the disease can go into remission, that they can carry the infection without showing signs of suffering any disease.
4. The disease was seen to spread from group to group by transfer of infected adult males, of which some posed a more severe risk as they had dual membership and could move back and forth daily between two groups.

Signs of the disease

The disease primarily affected the reproductive organs, and thus affected males and females rather differently:

Males: Were afflicted by moist lesions on, or especially under the folds of, the scrotum. The penis could also be affected, either on the glans, which in some cases eventually dropped off, or on the shaft, in some cases the lesions left scar which was not elastic so that the penis would become curved or would tend at an angle to one side. Also, the penis of baboons is partially retractable inside the skin of the abdomen, and in at least four cases, swelling caused it to become trapped inside, such that the male could not urinate properly (the urine trickles from the penis's atrium) and became unable to mate (mounting, thrusting, pausing, but no penis visible outside). Swelling and redness of the penis was common in adolescent and juvenile males as well as adults. Eventually, two adult males died in bad condition from the disease, two other adult males died when their penis had become trapped inside the abdomen, and two juvenile males also died due to urinary blockage from the swelling.

Females: Females appeared to suffer more, perhaps because their reproductive organs are more internal and may sequester pathogens more readily; but especially because their so-called sex-skin is adapted to swell and subside through the menstrual and ovulatory cycle, and is therefore already soft and labile. The most common signs were moist vaginal discharge often with blood, inflamed tissue visibly red in the anus, with behaviours of irritability and discomfort, frequently reaching back the hand to touch the perineal area; and especially signs of pain on defecation (sometimes with distress calls). In severe cases there could be loss of tissue between vagina and anus, such that mating sometimes comprised anal entry rather than vaginal. Many of these females ceased normal swelling cycles (amenorrhoea). Four adult females died in advanced stage of this disease, most likely because of it. One of these had periostitis on the right femur and tibia. In very few cases, females had lesions on the mouth area and lips.

Latency to onset

Case-histories among males give clues to the latency of this disease:

Two males came apparently healthy from an infected group into an uninfected group, but only developed signs after 3 and 5 months. Two males from uninfected groups moved into infected groups but did not develop signs till 4-5 months later. These suggest latencies between 3 and 5 months. When females are cycling, mating occurs in every month and it is hard to infer the interval between first infection and onset of disease. However those that first showed signs in late pregnancy or after birth indicate that infection may have remained latent since the last sexual cycle, even up to six months before. Although male-female sexual contact may occur during pregnancy, these cases suggest a latency of between 4 and 6 months.

Diagnosis

In October 1989, Dr Kenneth Pack, veterinarian from Jane Goodall Institute, Republic of Congo, used blow-darts to anaesthetise two infected males (one large juvenile – Sostiyi, and one adolescent male – Cactus), transported them by boat to Kigoma (for immediate access to a fridge), took biopsies and blood samples, treated their lesions. returned them to Gombe still under partial anaesthesia, released and watched them till recovery. Next day two more adult males were darted and their blood sampled on-site at Gombe. Diagnosis from these samples was returned as a spirochaete, Treponema pertenue, which is known for causing Yaws in humans.

Attempts to limit illness: Decision

The diagnosis or Treponema prompted discussion of whether to try to limit the disease, since yaws is easily treatable in humans, using penicillins. The main argument against this was because the policy in National Parks at that time was conservation by protection, to allow nature to take its course, without intervention against animal disease. The research principle of Jane Goodall also supported research being non-intrusive. However the non-intrusiveness of Goodall was principally for the well-being of the animals, which in this case could also argue for intervention. Intervention was also supported for five other reasons: to relieve the animals' evident suffering; to protect the subjects of the twenty-year research program; to remove aesthetic blemish (people living in the Park disliked seeing the lesions at close quarters every day, which tourists might see as deficiency by the management); to protect people and especially small children from the health risk posed by the baboons' perineal discharges; and to protect the health of the primary conservation target at Gombe, the chimpanzees. Their vulnerability was unknown at the time, but chimpanzees were known to be susceptible to almost all the diseases of humans, of which both Yaws (T. pertenue) and Syphilis (T. pallidum) are examples. The risk was that infected juvenile baboons might infect young chimpanzees, because their play together can include genital contact and sexual movements by either species.

The final consensus was that the disease should be limited so as to protect the health of the chimpanzees, (and possibly the people), and also to allow the baboons to recover (for animal-welfare and aesthetic reasons, and to conserve the research population).

Attempts to limit recurrence: treatments

Three methods were used, all of which required an open area with some scattered cover. Baboons were attracted to these sites by daily distribution of loose maize kernels. Maize was also used strategically to attract those particular individuals needing to be dosed and to selectively distract those which had already been dosed or which would interfere with the target individuals.

Method 1: Darting with anaesthesic, then injecting

(1a) Anaethestic was delivered in a dart from a blow-pipe, but some baboons evaded darting: mothers with young were more wary, and any baboon which had been hit but the dart rebounded became progressively harder to dart.

Table 3: The anaesthetics used by different veterinarians are summarised

Veterinarian	Ingredient 1	Ingredient 2	Ingredient 3	Notes
Pack: Adult dose i.e. 13-24 kg	Ketamine 30 mg.	Xylazine 37.5 mg.	Hyaluronidase 45 units	Juveniles: half adult dose, Newborns: 20% juv. dose
Wiik, Lukasik:	Ketamine HCl 5 mg/kg.	Medetomidine HCl 0.07 mg/kg		
Gray:	Zoletil			

Pack's dosage caused between 15 and 60 minutes anaesthesia, though some targets had to be topped-up again with 50 % dose to allow more processing time. Gray reported that Zoletil was very effective, i.e. produced very rapid anaethesia, but very slow recovery-time. Using his system, Pack was able to dart and treat 97 baboons in four days (Pack, 1990).

(1b) Injection:

Once anaesthetised, Pack injected an intravenous antibiotic for immediate effect and an intramuscular antibiotic for slower release over a longer time: both were penicillins (not specified). He took the opportunity to clean-up any necrotic tissue, and four males were operated-on to free the penis trapped inside the abdomen by swelling. He also collected blood-samples for immunology. While the baboon was still unconscious the team would weigh it, and clip shoulder-hair as a marker to prevent accidental repeat-darting.

Method 2: Darting with antibiotic directly, without anaesthetic.

This was tried once only, but successfully. One female would not take medicine orally (as in method 3 below), and so was darted directly by Prof. Gray,
injecting 1 000 000 U penicillin instead of anaesthetic. This causes little distress, because the female resumed feeding almost immediately just ten feet further away.

Method 3: Oral administration

The method was to attract the group, to administer the correct dose of antibiotic per body-size, concealed in a food, for enough consecutive days to complete the course to those individuals requiring it. Maize kernels were used to selectively attract or distract particular individuals. The most successful vehicle for the antibiotic was banana, usually a half-banana per dose; but occasional individuals refused or tired of banana, and those were dosed in fish (dagaa), or bread with margarine incentive.

The research team therefore had to be sure to identify the target individuals correctly, be ready to distract higher-ranking non-targets with maize or plain banana, and conceal to the last seconds which one was to be given the dose, to pre-empt theft. However, competition for food did have one advantage in that it forced the targets to eat very quickly and not reject the part that tasted different because of the antibiotic.

Antibiotics used

Table 4: Antibiotics used in treatment on the Gombe baboons

Antibiotic	Method	Dosages			
	Injection or Oral	Adult male	Adult female	Immature	Infant
Penicillin	Intravenous	n.d	n.d	n.d	n.d
Penicillin	Intramuscular	n.d	n.d	n.d	n.d
Penicillin	Dart injection	-	1,000,000 U	-	-
Ampicillin	Oral 8 days	250 mg	250 mg	125 mg	63 mg
Amoxycillin	Oral 8 days	n.d.	n.d.	n.d.	n.d.
Erythromycin	Oral 11 days	250 mg			
Clamoxyl	Oral 8 days	n.d.			
Azithromycin	Oral 3 days 10mg/kg	250 mg	250 mg	125 mg	63 mg

The injectable antibiotics were chosen by the veterinarians. The most important criterion for the success of the oral antibiotics was that they were palatable, for example Amoxycillin and Ampicillin taste much better than Penicillin. Individuals refusing these were given Erythromycin. Azithromycin had the advantage that the dose was only three days not eight, but it was less effective as a treatment. Some individuals persistently failed to recover, because they avoided the taste of antibiotic, and would refuse the food or separate-out the dose before eating. But for those which completed the eight-day course, these antibiotics were very effective.

Treatment protocols:

First treatment was in December 1989, when 97 baboons in C and D and A Groups were darted and injected: two who evaded were given oral treatment. A second round of injections was done in February 1990, when 49 baboons in C and D groups were darted, but the vet's time was short and 30 others had to have oral treatment later, while A Group was postponed to treat 50 members orally in March. After those treatments, the protocol was established that any new immigrant male was to be treated if he had signs of infection or if he came from an infected group nearby.

Regimes of treatment

After these initial treatments, two systems were used General and Individual.

General Treatments

In a group when many were infected, the aim was to treat all adults of both sexes, and young males above about 1 year's age. In practice, this was sometimes reduced to the sexually active individuals: all males from one year to old age, and all cycling or recently pregnant females; sometimes 1-2 immature females would be included if they showed signs of infection.

Individual Treatments

At times when only a few individuals had signs of infection, those few would be treated. These were usually ones which had not responded to the General Treatment, or had repeated relapses.

Table 5 compares these two regimes for the numbers of individuals treated and their percent coverage of the age-sex classes of the group. Thus General Treatments usually covered about 54 % of the group, while Individual Treatments covered only 5 %. Likewise 26 % of the General Treatments focussed on Adult males, between 3 and 13 at a time, but only 4 % the Individual Treatments did, only one at a time, because they focussed more on the intractable adult females.

Table 5: Comparison of General and Individual Treatments.

Treatment	Adult males	Adult females	Immature males	Immature females	Percent of group
General (18 times)	3-13 males	4-18 females	3-18 imm m	0-10 imm f	38-95 %
	26 %	35 %	34 %	4 %	54 %
Individual (15 times)	0-1 males	0-9 females	0-10 imm m	0-1 imm f	3-14 %
	4 %	56 %	37 %	3 %	5 %

The General Treatments were largely successful: afterwards, prevalence would drop to zero for some months, and if some did not recover completely, (either by evading the dart, rejecting the oral dose) then Individual Treatments would be carried-out. By definition Individual success rate was not so high, since they were already targeting individuals which had not responded to the normal cure.

Complications from treatment

One infant died because he was attacked by an infanticidal male before the mother had fully recovered from anaesthesia to protect him. One old female, and one adolescent female, died of unknown causes within one month of treatment (injection, and oral, respectively). One sub-adult male died 11 months after darting, and later was found to have a broken-off needle in the body. These deaths cannot be attributed with certainty to the treatments, but may indicate the risk.

C-Group had one outbreak lasting 44 months, and it was cleared with two general treatments and five individual treatments, after which it did not return. D-Group had two outbreaks separated by 10 months clear. A-Group had three main outbreaks but in the third long one the researchers abandoned treatment because although the few intractable females did not respond to antibiotic, yet they did not appear to be infecting others: and once they had died, one general treatment was given in January 2006 to clear the group.

In all, the table shows that these treatments could clear the signs of infection from some groups for months or often years. Possibly even they have assisted the baboons to acquire immunity. However it was known that some of the many other baboon groups in the park, outside the study area, must still be harbouring infections, and affected individuals were seen from time to time. In 1999 the disease was reported in groups living around the TANAPA HQ at Mitumba. In April 2002 one individual was darted and swab-sampled by TANAPA vet team as part of the Wildlife Health Worshop (Mlengeya 2002). TANAPA resumed treatment with assistance from the baboon research team in 2007-8. The first treatment of three groups was successful. However the disease lingered and necessitated further treatment in 2009, which has reduced the prevalence there to a very low level through until 2011.

History of treatments

Table 6: Treatments carried-out on C, D, A, and L Groups, and the groups further north near Park HQ.

Grp:	Dates of outbreak	Duration Months	Max Prevalence (n)	No of General Treatments	No of Individual Treatments.	Months or years clear after treatment.
C	6.88 – 2.92	44	48 % (42)	2 by injection	5	Clear 14 years to 2006 (end of obs.).
D	2.89 – 4.91	26	61 % (57)	2 injection, 1 oral	5	Clear 10 months.
D	Feb 1992	1	1 % (69)	1 oral	-	Clear 19 years to present 2011
A	10.89 – 6.90	9	7 % (58)	1 injection, 2 oral	-	Clear 6 years 8 months.
A	2.97 – 8.98	18	43 % (44)	2	3	Clear 1 year 9 months.
A	5.00 – 1.06	68	56 % (32)	1	Females did not recover	Clear 5 years 10 months to present
L	1.97 – 7.99	30	23 % (53)	1 injection 1 oral	4	Clear 1 year till end observations
HQN	2007-8	c 24	40 % (43)	1	-	under 1 year
HQM	2007-8	c 24	73 % (22)	1		under 1 year
HQS	2007-8	c 24	47 % (39)	1		under 1 year
HQ gps	2009	c 12	? n.d	1 per group		low level through 2011

DISCUSSION

Informed diagnosis

During the darting to treat against Treponema in 1989, three of the baboons were seen to have small lesions around the lips and the mouth, which had the appearance of herpes-sores. Suspicion about Herpes was raised again during 2002, when a sample of diseased baboons from both Gombe and Lake Manyara were found to be all infected with HPV-2. However, no control samples had been taken from baboons who did not have the disease, and HPV-2 was later found to be a common virus in healthy baboons in northern Tanzania, not necessarily associated with disease at all (A.E Makundi, cited in Fyumagwa et al., TAWIRI 2003). Finally, if the Gombe disease was caused by a virus such as Herpes, it would not have responded to the penicillins. So we favoured the original diagnosis of Treponema pertenue as the cause of the lesions, with possible Herpes as a secondary or associate in a few cases. More recent surveys in Lake Manyara and Serengeti areas suggest that the Gombe illness is one of several local variants of Treponema endemic in baboons in Tanzania and across tropical Africa (Knauf 2011, Knauf et al 2011, Harper et al in prep).

Why did this disease outbreak occur?

Gombe and Manyara are both rift valley escarpments with productive ground water forests which allow baboons to live at high population densities. The original study groups at Gombe had increased from 93 baboons in 1969, to 294 baboons by 2006 (showing that the genital disease since 1988 has not been able to stop this increase). Density there increased from 51 per sq km in 1969 (corrected from Ransom, 1981) to 99 per square km in 2002 (Grossmann, 2006). Meanwhile estimates of population at Manyara also show that the baboon density in both places is very high, 18-23 per sq km in 2004 (Knauf, 2011).

It can be expected that when baboons attain very high densities, with more contact and habitat-sharing between groups, and more adult males moving between them, pathogens can travel throughout the population with greater ease, and their effects will become more apparent (Freeland, 1976). High population density may also cause higher stress levels, bringing lower immune competence.

CONCLUSION AND RECOMMENDATIONS

Transmissibility to chimps

Since 1988 there has been no sign of genital infection in the Gombe chimpanzees, and it is difficult to know exactly what is the level of risk that chimpanzees are susceptible is now clear (Lovell et al., 2000) and it would be interesting to know whether the Gombe chimps have been exposed to Treponema without suffering disease, or whether they remain sero-negative.

Recommendation to intervene or not at Lake Manyara

The suggestion above that high population density may be a co-factor promoting the disease, accepts that it is a natural disease of baboons, not just a local disease-presence, and it will not be possible to stamp it out. The argument for intervening at Gombe to protect the prime conservation target, the chimpanzee, does not apply so well to Lake Manyara. The main issues applying at Manyara are compassion for the animals, and the aesthetic aspect and possible health risk for people, especially the tourists. We found that is difficult to treat all the sexually active baboons in a group so as to eliminate all infections. And it would be harder if those baboons were not so well habituated to human presence. It may therefore be practical at Manyara to intervene to reduce the levels of infection in the groups which have most contact with park staff, surrounding villagers, and tourists, but it will probably not be possible to eliminate it from the Park.

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RIFT VALLEY FEVER: A DISEASE OF THE POOR AND A PROFESSIONAL HAZARD

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ABSTRACT

Rift Valley Fever (RVF) is an arthropod borne viral disease affecting livestock (cattle, sheep, goats and camels), wildlife and humans caused by Phlebovirus. It occurs in periodic cycles of 4-15 years associated with flooding from unusually high precipitations in many flood-prone drylands. Aedes and Culex spp and other mosquito species are important epidemic vectors. Because of poor living conditions and lack of knowledge on the pathogenesis of RVF, nomadic pastoralists and agro-pastoralists are at high risk of contracting the disease during epidemics. RVF is a professional hazard for health and livestock workers because of poor biosafety measures in routine activities including lack of proper Personal Protective Equipment (PPE). The episodic nature of the disease creates special challenges for its mitigation and control and many of the epidemics happen when the governments are not prepared and have limited resource to contain the disease at source. This review is on the epidemiology, policy issues, and outbreak reporting, public awareness, preparedness and control strategies for the zoonosis.

INTRODUCTION

Rift Valley Fever (RVF) is a multi-host arthropod-borne viral haemorrhagic disease affecting livestock, humans and occasionally wildlife (Harper 2004; Evans et al. 2008). RVF is an acute, febrile viral disease accompanied by a wave of abortion and perinatal mortality in livestock (sheep, goats, cattle, and camel). In humans it is a febrile or influenza like illness that can be associated with fever (104 to 106OF), severe headaches, muscle and joint pains, anorexia, high respiration rate, vomiting, diarrhoea, hepatitis, jaundice, marked leucopoenia and extreme eye pain with sensitivity to light (photophobia). Few severe fatal haemorrhagic syndrome cases have occurred as a consequence of hepatic necrosis, myocarditis, renitis and/or encephalitis (Daubney et al. 1931; Harper 2004; Davies 1981; Fraser 1986; Harper 2004; Mohammed et al. 2010; Munyua et al. 2010). It is caused by an RNA virus, a member of the Bunyaviridae

family, Phlebovirus genus and is associated with periodic outbreaks, mostly on the African continent. The virus is transmitted by mosquitoes (Aedes, Culex spp) and other blood sucking insects such as the sandfly of the Phlebotomus species (Linthicum et al. 1985; Fraser 1986; Logan et al. 1992; Jup et al. 2002; Flick et al. 2005; Harper 2004; Amwanyi et al. 2010; Song et al. 2010). Recent entomologic investigations to determine the epidemic vectors of RVF have identified 10 mosquito species, including three Aedes spp, one Anopheles sp, four Culex spp, and two Mansonia spp in Kenya (Song et al. 2010). Flooding of mosquito habitats can introduce Rift Valley Fever Virus (RVFV) into domestic animal populations by production of infected Aedes mosquitoes while epizootic/ epidemic cycles are driven by the subsequent elevation of various Culex mosquito populations, which serve as secondary vectors if mosquito habitats remain flooded long enough (Linthicum et al. 1999; Amwanyi et al. 2010).
The clinical signs in calves include anorexia, high rectal temperature (up to 106OF), blood-stained nasal and lachrymal discharges, a high respiration rate, and prostration, lateral recumbence with opisthotonous, respiratory distress and death (Davies 1981). Exotic breeds are more susceptible to RVF infection than indigenous sheep, goats and cattle, and recovering animals from RVF develop life long immunity (Davies 1981). Female mosquitoes are also capable of trans-ovarial transmission of the virus to offsprings leading to synchronous new generations of infected mosquitoes hatching from eggs (Linthicum et al. 1999; WHO 2007; Amwanyi et al. 2010). This accounts for the continued presence of the RVF virus in enzootic foci and provides the virus with a sustainable mechanism of existence as the eggs of these mosquitoes can survive for several years in dry conditions. Infected mosquitoes can be transported for long distances in low-level wind or air currents, which may lead to the rapid spread of the virus from region to region or even internationally (Song et al. 2010). Despite the existing knowledge on RVF limited research work has been conducted in wildlife in Tanzania.

Epidemiology of RVF

The disease was first recognized and characterized in the Great Rift Valley of Kenya in 1913, hence its name. However, since the 1930’s when it was first described (Daubney et al. 1931) the understanding for the epidemiology and diagnostic capabilities have progressed a great deal. In the 1930’s the causal agent was only described as a Bunyammwera-like virus but now it is clearly known as a Phlebovirus (Linthicum et al. 1985; Logan et al. 1992; Harper 2004). RVF had been frequently occurring in Kenya, Tanzania and Uganda; however, the most notable epidemic was recorded in Kenya in 1950-1951, which resulted in the death of an estimated 100,000 sheep (Logan et al. 1992; Shieh et al. 2010). Another epidemic was recorded in East Africa in late 1997, after exceptionally high precipitation (El Nino), which resulted in the death of at least 300 people and large numbers of animals in remote parts of Northern Kenya, southern Kenya and southern Somalia (Munyua et al. 2010; Shieh et al. 2010). Using the NASA Meteorological information, early warning exists to predict the possible location of RVF epidemic for preparedness in disease control (Harper 2004; Breiman et al. 2010).

Concurrent infections of RVF with other viral or bacterial or protozoal infections exacerbate the severity of RVF epidemic with high fatality rates (Mohamed et al. 2010). The major risk factors associated with human cases in nomadic pastoral and agro-pastoral communities are contact with sick animals and animal products including blood, meat and milk (Mohamed et al. 2010). High precipitation with flooding in areas of high density of livestock creates a conducive environment for RVF outbreak (Mohamed et al. 2010; Nguku et al. 2010).

Confirmation of RVF cases in humans and livestock is through detection of immunoglobulin M (IgM) antibodies by Enzyme Linked Immunosorbent Assay (ELISA), detection of viral RNA by real-time reverse transcriptase polymerase chain reaction (RT-PCR) or detection of viral antigens in liver tissue biopsies by immunohistochemistry, demonstration of viral antigens in hepatocytes and kupffer cells by immunoperoxidase assay and histologically by demonstration of extensive hepatocellular necrosis with acidophilic materials in cytoplasm (Arborio & Hall 1989; Van der Lugt et al. 1996; Mohamed et al. 2010; Shieh et al. 2010). Severe RVF infection in humans can persist for an average of more than 30 days before recovery or death with more than 80% of the patients exhibiting high rate of encephalopathy (Mohamed et al. 2010). Outbreak detection, etiologic confirmation and public health responses in 2006/ 2007 epidemic were made possible by advances in communication, diagnostic technologies like RT-PCR and local diagnostic capacity (Breiman et al. 2010; Nguku et al. 2010). However, the impeding factor in containing the disease at source was lack of resources to execute control activities.

RVF virus is cytopathic and tends to target the liver causing focal hepatic necrosis and in brain causing necrotic encephalitis (Harper 2004; Shieh et al. 2010). Pathologic festures of extensive diffuse hepatocellular necrosis without prominent inflammatory cell infiltration is the most distinctive histopathologic change in liver tissues infected with RVFV (Shieh et al. 2010). This histopathologic change is consistent with immunohistochemistry and is an important differential diagnosis of RVF against other hemorrhagic fevers e.g. yellow fever, ebola, crimean-congo hemorrhagic fever, Lassa fever virus, and Marburg virus (Coetzer 1982; Shieh et al. 2010). The lytic virus-cell interaction in liver which involves direct virus-induced hepatic cell necrosis is the major pathogenesis of RVFV infection (van der Lugt et al. 1996; Shieh et al. 2010). Genetic analysis of selected regions of virus S, L, and M RNA genome segments indicate little genetic variation among viruses associated with disease, and even the Saudi Arabia and Yemen viruses were identical to the isolates from East Africa (Shoemaker et al. 2002; Balkhy & Memish 2003).

In Kenya livestock cases were detected after human cases in most of the regions of the country, partly because of limited resources which lead to inadequate surveillance in livestock (Munyua et al. 2010). ILRI (2008) established that the severity of RVF epidemic is normally exacerbated by delays in recognizing risk factors and in taking decisions to prevent and control the disease. Contact with animal body fluids, sheltering livestock inside the home, consumption of products from sick animals and to a lesser extent being a herdsperson are the main risk factors associated with RVF infection (Woods et al. 2002; Amwanyi et al. 2010). Direct exposure to infected animals can occur during handling and slaughter or through veterinary and obstetric procedures or handling of specimens in laboratory (Chambers & Swanepoel 1980; Frank & Jeffrey 2001; Amwanyi et al. 2010).

Policy and institutional environment on RVF

Tanzania has developed an emergency preparedness plan for RVF whose implementation will take into consideration the existing policy reforms, public sector reforms, liberalization of trade, privatization of health and animal health service delivery and decentralization. Health policy includes Health Sector Strategic Plan III (HSSP III), Health Sector Policy and Health Sector Reforms which are in line with the National Livestock Policy of 2006 (URT 2010:3)

The National Livestock Policy recognizes RVF as a Transboundary Animal Disease (TAD) and a zoonotic disease with socio-economic and public health significance and therefore aims to control and prevent, in order to protect animal and human health, sustain the livestock industry and stimulate trade.

The plan is guided by the Disaster Management Policy of 2004 with regard to prevention, preparedness, response and recovery from RVF outbreak since the disease has been declared a disaster. The Department is also responsible for resource mobilization, coordination and management of the plan. According to this policy and the National Operational Guidelines, the Lead Ministries are those responsible for animal health, human health and wildlife. In complementing this plan other relevant Ministries and Institutions will be responsible for implementing their respective roles as stipulated in the document.

The countries at risk have a number of challenges to address for the prevention and control of RVF such as:-

- Surveillance systems for early detection and response for RVF in both humans and animals are not adequately operational due to limited funds.
- Inadequate maintenance of standard bio-security practices in livestock production enhancing disease introduction and spread.
- Inadequate management of livestock and livestock products movement.
- Inadequate marketing systems for livestock and livestock products.
- Low public awareness in prevention and control of RVF.

Networking in RVF surveillance will ensure that a dialogue with local traders and international trading partners is maintained in order to make sure that they are aware of the current RVF risk status and the need to support National Rift Valley Fever Emergency Preparedness and Response Plan (RVF EPRP). The realization of this objective depends on individuals and institutions whose activities relate to medical, veterinary and wildlife services (URT 2010).

Outbreak reporting and routine surveillance

Timely outbreak response requires effective early warning and surveillance systems. Previous evidence points out the important role that livestock keepers can play in veterinary surveillance (Mariner & Paskin 2000; Jost et al 2007; Grace et al 2008) Timeline and matrix scoring results showed that the pastoralists, especially the Somalis in North Eastern Kenya, were aware of the unusually heavy nature of the rains and flooding before the outbreak of RVF in their areas, noticed mosquito swarms that were unusual because of their intensity and the physical characteristics of the species involved (Aedes spp.), and noted unusually high morbidity and mortality in their flocks consistent with RVF (Linthicum et al 1987; Linthicum et al 1990; Woods et al 2000). These facts were common knowledge among livestock owners well in advance of the detection of RVF by veterinary service surveillance systems. They also noted human cases consistent with RVF well in advance of detection by the public health surveillance system (Breiman et al 2008; Anyamba et al 2009). This suggests that veterinary surveillance systems could detect RVF outbreaks earlier by taking advantage of livestock owner observations through the integration of active syndromic surveillance, such as participatory disease surveillance (PDS) geared to the level of outbreak probability (Mariner & Paskin 2000)

Rainfall data is therefore a useful predictive tool for epizootic RVF, either by actual recording or from data derived from Remote Sensing Satellite Imagery Data (RSSD). The monthly analysis of this data in the region is valuable for risk assessment of RVF virus activity. Currently, FAO/EMPRES, IGAD, Climatic Prediction and Application Centre (CPAC) and other regional and national meteorological centers are carrying out the analysis on a monthly basis. The US Department of Defense "Global Emerging Infections Surveillance and Response Systems" (GEIS) gives early warning for RVF (URT 2010).

The forecast model used in 2006/7 incorporated data on vegetation changes (normalized difference vegetation index, NDVI) that occurred only after conditions were in place for an RVF outbreak. In Tanzania, the Integrated Diseases Surveillance and Response (IDSR) which reports priority diseases weekly and response is done promptly when requested (MoHSW 2010).

It has been established that, the immune status of animals, herd movements and local conditions favoring the reproduction of mosquitoes play a more significant role in the inter-annual variability of RVF outbreaks. The occurrence of RVF can be endemic or epidemic, depending on the climatic and vegetation characteristics of the regions.

African agro-climatic zones can be used as a good guide of RVF virus activity:

(a) endemic activities (+/-cryptic RVF) in high rainfall forests and forest edges
(b) periodic increased RVF-virus activity to epidemic proportions in bushed and wooded grasslands following long standing floods
(c) rare but explosive epidemics in dry grassland and semi-arid zones if associated with heavy seasonal rainfall and floods.

In response to initial warnings, national stakeholders could reinforce local climate monitoring and disease surveillance in known high risk areas, and alert response systems to begin preliminary mobilization of resources (Clements et al 2007; ILRI/ FAO 2009).

RVF awareness among scientists and the lay community

Limited awareness about RVF is one of the factors explaining limited and uncoordinated response to RVF outbreaks. Awareness about RVF signs and its clinical manifestations and knowledge on early warning is still low among lay community members particularly agro-pastoral communities (Jost et al., 2010). Research evidence from Kenya shows that community understanding of risk practices (eating raw meat, or unpasteurised milk, touching and herding aborted animals and consuming products from such animals) is still limited (Amwayi et al 2009)

In the 2006/ 2007 RVF epidemic, the Maasai of northern Tanzania and Somali nomadic pastoralists of North Eastern Kenya had different levels of traditional knowledge concerning livestock diseases. The latter provided more detailed and accurate clinical descriptions of diseases affecting livestock including RVF, had greater appreciation of the risk factors associated with the disease, and showed a stronger recall of the outbreak history (Jost et al., 2010). It is agued that the Maasai now have less ability to utilize indigenous knowledge on diseases due also to dependence on ecotourism and crop cultivation for their livelihoods, and have greater access to veterinary services (Jost et al. 2010). As RVF happens in cycles of 4 to 15 years it is difficult for them to recognize the start of an RVF outbreak; moreover, it is difficult to differentiate RVF from tick-borne diseases, which are the number one killer of livestock in East and Central Africa (Lynen et al. 2007; Fyumagwa et al. 2007; 2011).

In the outbreak of 2006/ 2007 in East Africa, medical and veterinary personnel were well informed about the RVF epidemic, as evidenced for example by how they handled the first index cases abiding with biosafety precautions despite limited resources (Mohamed et al. 2010). Entomological investigation in Kenya to establish the epidemic vectors began in December 2006 while the government intervention to prevent spread of the disease began in February 2007. In Tanzania despite the high infection rate of over 500 human cases with 144 fatal cases (28%) and a mortality 16,973 cattle, 20,193 goats and 12,124 sheep, no medical or veterinary personnel contracted the infection (MLDF 2008; Mohammed et al. 2010). Health education campaigns to prevent transmission of the RVF virus through handling or consumption of infected animals were implemented including pictorial narratives explaining “do not slaughter, skin, milk or provide obstetrical procedures to sick animals, bury or burn carcasses during an outbreak, boil milk, wear personal protective equipment (PPE) e.g. gloves, coveralls, boots, eyewear, and mask when handling sick animals and products, avoid contact with infected tissues, blood, milk, meat aborted fetuses and sick animals” (Amwanyi et al. 2010).

National Preparedness plans

Retrospective data from 1912 shows recurrence of disease in the same locations suggesting that targeted control measures such as livestock vaccinations in high risk areas before the onset of the outbreak can minimize the impact of the disease (Munyua et al. 2010). Unfortunately, none of the countries at risk had preparedness plans and even in the recent outbreak of 2006/ 2007 the affected East African countries did not have contingency plans for response to RVF when FAO issued an alert on a possible outbreak. This delayed the implementation of response activities and the efforts made in providing vaccination to livestock at risk did not contribute much in preventing the spread of the disease (Jost et al. 2010; Munyua et al. 2010).

The preparation of NRVF EPRP in East Africa is the commitment to strengthen emergency preparedness and response against possible re-occurrence and spread of RVF. Tanzania on the other hand has established the Zoonotic Diseases Emergencies Task Force (ZDETF) which will take responsibility of controlling all zoonotic diseases disasters.

The Ministries responsible for Livestock Development and Health have jointly been controlling previous outbreaks of RVF in an ad hoc manner through Ministerial contingency plans. The preparation of the current NRVF EPRP has therefore taken into consideration the desires of the previous ministerial plans. The NRVF EPRP measure takes into consideration the dynamics of RVF virus and environment, scientific and technological advances, improved surveillance procedures, change of national and international policies and legislations and stakeholder’s interests. The NRVF EPRP preparation process followed the FAO/OIE/WHO and USAID guidelines. The preparedness plan is in line with the National Livestock Policy of 2006 and has been harmonized with the Regional RVF emergency preparedness and response plans such as those of East African Community (EAC), Southern Africa Development Community (SADC), African Union – Inter-African Bureau for Animal Resources (AU-IBAR) and Regional Indicative Strategic Development Plan (RISDP).

Suggestions have been put forward that higher specificity of forecast models will be needed to be confidently used to activate action steps which require commitment of limited public and animal health resources. The specificity may be increased by including animal surveillance to establish the degree of herd immunity and entomologic surveillance to identify potential for disease spread (Breiman et al. 2010). Timely prevention and control of RVF epizootics will significantly reduce the scale of impacts of the disease on lives, livelihoods and local national and regional economies. Close collaboration between veterinary services and public health sectors are essential for the effective prevention and control of RVF and other zoonoses.

The currently available Smithburn vaccine has a shelf–life of around 4years, while the interval between outbreaks tends to be around 10 years or even 20 years during some inter-epidemic periods. Because of limited resources the veterinary authorities become reluctant to maintain vaccine stocks for RVF which are likely to expire before they are used. Manufacturers also avoid maintaining large stocks, which are likely to reach expiry dates before they can be sold. In the longer term, new and improved vaccines that have longer shelf-lives may be developed to overcome this problem or earlier warning systems may be developed that provide manufacturers with the lead time required (Geering & Davies 2002).

Collaboration in management and control of RVF outbreaks

Since its first detection, there have been numerous outbreaks; however, the 2006/07 epidemic underlined the need for collaboration among different actors, institutions and countries in controlling the spread of the outbreak. Evidence shows that control measures that were taken in Tanzania and Kenya mirrored the multidimensional nature of RVF. It included closing livestock markets and butcheries, imposing movement controls and quarantines, and providing advice warning against drinking raw milk, slaughtering animals, or eating uninspected meat. Collaboration is not only confined to outbreak control but also in the strengthening of outbreak preparedness (ILRI/FAO, 2009 cf Jost el al 2010). The tool is based upon the identification of key decision points in the progression of events leading up to an outbreak, and allows investment in mitigations to be balanced against the escalating level of risk of an outbreak. The concept is that a phased response minimizes the risk of incorrect decisions and maximizes preparedness in the event of an outbreak (Clements et al 2006).

The initial step for RVF control is a ban on raw milk, home slaughter, animal quarantine and placing community health workers armed with health messages at points of congregation of high risk individuals e.g. watering holes for livestock and market places. Response and mitigation should focus on; (i). Initiation of enhanced surveillance activities (ii). Imposition of animal movement restrictions/ quarantines (iii). Mosquito control programs including distribution of mosquito nets and livestock dipping with insecticides (iv). Dissemination of public information to mobilize social and cultural activities directed at reducing human contact (v). Implementation of specific domestic animal vaccination (Amwanyi et al. 2010).

CONCLUSION

Many of the RVF epizootic/ epidemic have affected pastoral and agro-pastoral livestock and people themselves. Pastoralists and agro-pastoralists are the people who live below the poverty line; therefore, when RVF outbreaks occur they are normally unable to report the disease outbreak to the veterinary office or medical facilities because of remoteness. The major risk factors associated with human cases in nomadic pastoral and agro-pastoral communities are contact with sick animals and animal products including blood, meat and milk. High precipitation associated with flooding in an area of high density of livestock create conducive environment for RVF outbreak. The life style of nomadic pastoralists and agro-pastoralists is also one of the risk factors for contracting the infection. The episodic nature of the disease creates special challenges for its mitigation and control and many of the epidemics happen when the governments and communities at risk are not prepared and have limited resource to contain the disease at source. Concurrent infection of RVF with other viral or bacterial or protozoan infections exacerbates the severity of RVF epidemic with high fatality rates. Pastoralists and agro-pastoralists reside in areas where there is poor or no health facilities. In the event that RVF outbreak occurs these people are normally exposed to multiple infections including protozoa, bacterial and viral infections. Inadequate maintenance of standard bio-security practices in livestock production and lack of proper Personal Protective Equipment (PPE) predisposes animal workers and medical personnel to contracting the infection during routine professional practices. In general the surveillance systems for early detection and response for RVF in both humans and animals are inadequately operational due to limited funds.

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A COMPARISON OF DOMESTIC DOG POPULATION DYNAMICS IN VILLAGES INSIDE AND OUTSIDE A RABIES VACCINATION ZONE WEST OF SERENGETI NATIONAL PARK, TANZANIA

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ABSTRACT

Free-roaming domestic dogs (Canis familiaris) are a conservation and public health concern in Tanzania because they are a reservoir for rabies. In villages west of the Serengeti National Park, dogs have been vaccinated annually for rabies since 2003. As a result the incidence of rabies has declined in human, dog, and wildlife populations, yet the full impact of the vaccination program on dog population dynamics remains unclear. In 2010, we established a longitudinal study with the primary objective to determine whether the domestic dog population within the vaccination zone is changing as a result of the annual rabies vaccination campaign. This information is vital to the continued planning, execution and success of dog vaccination programs bordering the Serengeti National Park and other areas with dog-wildlife conflicts. In order to do this we are characterizing and comparing dog demography (survival, fecundity, mortality, and population growth), welfare and ownership practices in villages inside (n=2) and outside (n=2) the dog rabies vaccination zone west of Serengeti National Park. We are using mark-recapture methodology and household questionnaires to follow individual dog life histories over a period of 4 years. Welfare indices are being characterized using endocrine measures of fecal stress hormone and immunoglobulin-A concentration as well as body condition score. Finally, ownership practices, such as dog vaccination participation, population control, dog feeding, and parasite prevention, are being evaluated through household questionnaires. We will present preliminary results of data collected in 2010 and overall project strategy for the forthcoming field seasons. Understanding how factors of demography, welfare and ownership practices affect dog population ecology in the context of the Serengeti ecosystem will provide valuable information for future dog vaccination campaigns.

INTRODUCTION

The population processes of reproduction, survival, emigration and immigration are influenced by abiotic factors, such as climate, as well as biotic factors, including interactions with other organisms (Williams et al. 2002). Population growth of wildlife is typically limited by resources and interactions such as predation and competition. Domestic animals provide a sharp contrast. Humans typically control and limit population growth through selective breeding and restriction or facilitation of movement. Free-roaming and freely-breeding domestic dogs (Canis familiaris) are a peculiar case because their population dynamics are only partially or sometimes controlled by humans. In fact, much like wildlife, free-roaming domestic dog populations are affected by predation, resource availability, and disease. However, human intervention is involved through restriction, feeding, vaccination, and control of reproduction (e.g. killing puppies, castrating males, restricting females in heat). All of these interventions can directly influence dog reproduction, survival, emigration, and immigration, and affect the exposure of dogs to predation and disease. The Serengeti ecosystem in Tanzania poses a unique opportunity to study these relationships because of the interconnectedness of wildlife, humans, and domestic animals. Here, humans, wildlife and domestic dogs interact on a regular basis, through cattle herding practices, and livestock predation, for example. Disease is one factor that links these populations and has drastic implications for wildlife, humans and domestic animals.

Domestic dogs are a reservoir, or host source, for diseases such as rabies and canine distemper. These viruses threaten wildlife such as lions (Panthera leo), spotted hyenas (Crocuta crocuta), and African wild dogs (Lycaon pictus) (Roelke-Parker et al. 1996; Woodroffe et al. 1999; Kat et al.1995; Cleaveland et al. 2007; Lembo et al. 2007; Alexander & McNutt 2010). Moreover, dogs also contribute to public health concerns. Domestic dogs are the primary disease reservoir for rabies transmission to people (Cleaveland et al. 2002; WHO 2005; CDC 2007). Dog bites cause more than 90% of human rabies cases worldwide (Cleaveland et al. 2006; Kat et al. 1995; CDC 2007; WHO 2005). Rabies causes an estimated 55,000 human deaths in Africa and Asia (Cleaveland et al. 2002; Coleman et al. 2004), with an estimated 1,500 human deaths in Tanzania alone (Hampson et al. 2009).

To reduce the threat of rabies transmission to humans, dogs and wildlife, domestic dogs have been vaccinated for rabies, distemper and parvovirus in villages surrounding Serengeti National Park since 2003. These annual vaccination campaigns, currently coordinated by a consortium led by Lincoln Park Zoo, have reduced the incidence of rabies in dogs, humans and wildlife (Cleaveland et al. 2007; Lembo et al. 2008). The long term implications of these vaccinations on the domestic dog population, however, are unknown. A decline in disease incidence could increase dog reproduction and survivorship and change dog population growth rate. Such changes could dramatically impact future dog vaccination campaigns as more dogs will require vaccinations. An increasing dog population could also pose challenges for dog owners struggling to provide food for their dogs. This research aims to determine what factors regulate the free-roaming domestic dog population and how vaccination affects dog population dynamics.

The Serengeti offers a unique opportunity to characterize the population ecology of a free-roaming domestic animal interacting with humans, wildlife and other domestics simultaneously. Here, large populations of both vaccinated and unvaccinated free-roaming domestic dogs live in close proximity to wildlife, but are still dependent on humans for food. These dogs are somewhat managed by their human owners, yet are predated upon by wildlife regularly and tend to breed freely. Furthermore, the population has been “altered” by vaccination, which affects disease incidence, one of the factors that may limit population growth.

This research is innovative as such changes have not been documented in depth in this or any other large-scale rabies vaccination campaign. Previous research near Serengeti suggested that dog survivorship in vaccination villages is significantly higher than in non-vaccination villages (Kaare 2007). Other studies in the Serengeti and Kenya have also suggested that overall the dog population is increasing by 5-10% per year (Cleaveland et al. 2006; Kitala et al. 2001). These estimates were based on extrapolating information from human population growth projections and the human: dog ratio. The increase in dog populations could be a result of increasing demand from the growing human population, or it could be a result of or compounded by a decrease in disease incidence within the dog population. Regardless, dog population ecology must be examined further to understand how dog population dynamics may change in response to the benefits of vaccination.

Previous free-roaming dog studies from around the world have a disease focus and rely on owner survey data to track dog demographics (Beran 1982; Beran & Frith 1998; Butler & Bingham 2000; Matter et al. 2000; Kitala et al. 2001; Butler et al. 2004; Flores-Ibarra & Estrella-Valenzuela 2004; Kaare 2007; Knobel et al. 2008; Ratsitorahina et al. 2009; Acosta-Jamett et al. 2010; Alexander & McNutt 2010). While these studies provide some insight into free-roaming dog ecology, most were short term ($\leq$ 1 year duration) and therefore not able to explain how dog populations change in response to management interventions such as vaccination. Many free-roaming domestic dog studies involve only one survey or one sampling period (Flores-Ibarra & Estrella-Valenzuela 2004; Ratsitorahina et al. 2009; Kitala et al. 2001; Butler et al. 2004), which can provide a snapshot of dog ecology at that time, but may fail to capture changes that could impact the population long term. Investigating this population of dogs for four years will provide better estimates of population parameters.

Furthermore, we are incorporating dog welfare and ownership practice data with household questionnaires to include multiple aspects of dog ecology. Ownership practices, such as vaccination participation, restriction, and population control are a vital part of the ecology of free-roaming domestic dogs and the wildlife species to which they are ecologically connected. This unique three-pronged approach of household questionnaire surveys, longitudinal dog tracking, and individual dog welfare metrics will provide much needed insight into the ecology of domestic dogs, one of the most wide spread carnivores on the planet.

Objectives

The objectives of this research are:

1. What are the factors or combinations of factors (humans, disease, resource availability, wildlife predation) regulating free-roaming domestic dog population growth?
2. Do vaccination campaigns change dog demography, welfare, and/or ownership practices?

METHODS

Research is conducted in four villages located in the Shinyanga region west of Serengeti National Park (Figure 1) in Tanzania. Two vaccination villages (Nangale and Sanungu) are located within the current vaccination zone in Bariadi District. Two control villages (Buyubi and Iyogelo) are located outside the current vaccination zone in Maswa District. All four villages are agro pastoralist and of Sukuma tribal affiliation. Each village is composed of 4-8 subvillages, which are groups of households in the same general location within the village.

Research began in August of 2010, when we marked 225 dogs in Buyubi, 215 in Iyogelo, 224 in Nangale and 213 in Sanungu (total: 877 dogs) to identify and follow individual dog life histories. We collected 420 household questionnaires from owners of marked dogs.

Household selection

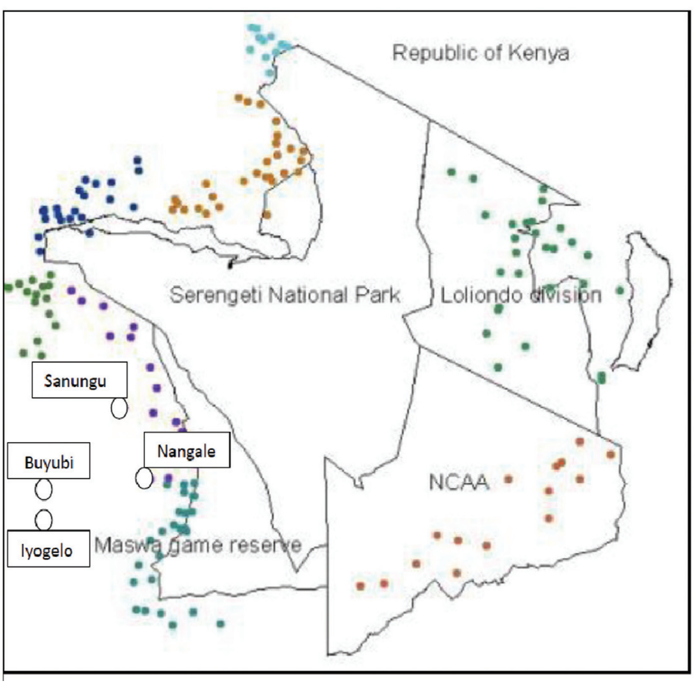

Fig 1: Map of Serengeti National Park. Colored dots correspond to villages receiving annual domestic dog vaccinations (colors indicate different districts). The four study villages have been labeled. (Modified from Cleaveland et al. 2007)

Households for inclusion in the research were selected in 2010 based on presence of dogs, willingness of owners to participate in the research, and manageability of dogs. Households from each subvillage are sampled to account for variation (economic and geographical) within the village. Permission to enroll dogs in the study and collect household questionnaire data is obtained from the head of household (or an adult over 18 years old) at the beginning of each household visit with a signed Kiswahili consent form.

Household questionnaire

The household questionnaire is modified from the existing questionnaire currently used by our collaborators in the Serengeti Health Initiative for disease monitoring in vaccination villages (Cleaveland et al. 2003; Lembo et al. 2010). The questionnaire includes questions pertaining to the household and basic information about their dogs (name, age, sex), female dog reproductive events within the last year, and ownership practices (role of dog, frequency of feeding, type of food, population control measures, etc.). The questionnaire is administered in Kiswahili and Kisukuma.

Dog selection/identification

Dogs are marked with ear tattoos and photographed. We attempt to mark all puppies and dogs present in the household with a unique number ear tattoo. Basic data such as name, age and sex are collected on dogs that are too aggressive to handle. This procedure maximizes our capture of dogs for study inclusion.

Dog characteristics, health and welfare data

Once restrained and muzzled, dogs are photographed and assessed for general health and welfare characteristics including age, sex, reproductive status, body condition score, presence/absence of fleas and ticks, and presence/absence of wounds and scars. Fecal samples for endocrine analysis are collected opportunistically with a fecal loop. Fecal corticosterone metabolites (FCM) and Immunoglobulin A (IgA) are extracted using a field extraction method (Santymire & Armstrong 2010) which renders the samples stable at room temperature until they are analyzed in the Endocrinology Laboratory at Lincoln Park Zoo in Chicago. In the laboratory, FCM are extracted and analyzed with an enzyme-immunoassay (EIA) using methods described by Munro & Stabenfeldt (1984) and Santymire& Armstrong (2010).

Data collection

All study households will continue to be revisited annually for 3 years (Aug-Dec 2011, 2012, and 2013). All marked dogs will be recaptured, identified, reassessed for health and welfare characteristics, and photographed. Fecal samples will be collected opportunistically for endocrine analysis. Household questionnaire data is collected from each household, including information about missing and/or dead dogs previously enrolled in the study. New puppies and/or acquired adult dogs in study households are marked and enrolled in study. If dogs are not present or unable to be assessed, we confirm their identity with photographs on a netbook.

Data Analysis

Depending on “capture” or detection probability, mark-recapture models and/or population models will be used to determine survivorship and population growth rate. Possible models include Kaplan-Meier survival analysis, or the product limit method, to estimate temporal variation and determine differences between dog survival in vaccination and control villages. This method has been used to show differences survivorship in between sex and age classes in Tanzania and Kenya (Kaare 2007; Kitala et al. 2001). This method could be particularly useful in this study because it can incorporate staggered entry (additional dogs added into the study after the first year) and right censoring (inability to recapture dog in subsequent years due to owners moving away, or dog disappearance, but not necessarily death) (Williams et al. 2002; Gordis 2004). A log-rank test will then be used to compare survivorship between vaccination and control villages, as well as between sexes and age specific categories (Williams et al. 2002).   Alternatively, mark recapture models such as Cormak Jolly Seber models could be used to estimate survival if we are unable to determine dog abundance (Lebreton et al. 1992; Sandercock 2006; Williams et al. 2002). Such encounter histories could be used in survival estimation using program MARK (White & Burnham 1999). These have not been used in most previous dog studies because these studies did not mark and recapture individual dogs and most studies were short term (For example: Butler & Bingham 2000; Kitala et al. 2001; Acosta-Jamett et al. 2010).

Reproductive rate will be estimated with life tables based on individual female histories following the method outlined by Caughley (1977). This method can be used to estimate fecundity (mx), which can then be used to estimate population growth rate (r) using Lotka’s equation (Caughley 1977). This has been applied to dog studies in Chile (Acosta-Jamett et al. 2010) and Zimbabwe (Butler & Bingham 2000).

Population growth could be derived from age class specific life tables as described above (Caughley 1977). Kaare (2007) used Leslie matrix models, where age specific vital rates were used to generate population growth. This method could be used in this analysis, particularly if the age distribution is not stable (Case 2000), or Lotka’s equation could be used to estimate population growth (Caughley 1977). Calculated dog population growth will be compared to annual village census data.

Dog welfare and ownership

Descriptive statistics of all measures of health status will be performed using SAS 9.2 program for Windows. ANOVA will be used to compare FCM and IgA concentrations in vaccination and control village samples. Comparisons will also be made between vaccination status within vaccination villages, sexes, age classes, reproductive states (castrated vs. intact, nursing vs. non nursing), feeding frequency, body condition score, and owner reported wildlife sighting frequency.

Preliminary Data

Fecal samples were collected from individual dogs (n=272; 129 females and 143 males) from each of the four study villages. Mean fecal corticosterone metabolite (FCM) concentrations did not differ ($F_{1,270}$= 0.843, p=0.36) between male and female dogs. Mean FCM also did not differ between dogs from the vaccination and non-vaccination zones ($F_{1,270}$= 0.001, p=0.98; vaccination: 621.4ng/g; control: 619.8 ng/g). FCM concentrations were not influenced by body condition score (scale of 1-9; 1=poor, 5=ideal, 9=obese) ($F_{3,108}$=0.6, p=0.825), or hyena sighting frequency (never, monthly, weekly, daily) in dog household ($F_{3,108}$=0.85, p>0.4).

Preliminary data from the ongoing 2011 field season revealed a 35% one year mortality rate in our marked sample of dogs and 39% mortality in our overall sample (including unmarked dogs and puppies) in Buyubi village (non-vaccination). In Nangale village (vaccination), the mortality rate was 37% of our marked dogs and 33% of the overall sample. In Sanungu village (vaccination), the mortality rate was 32% of our marked dogs.

In Buyubi village (non-vaccination village), owners reported that 28% of the marked dog deaths (78 total) was due to hyena predation while 64% was due to sickness. In Nangale village (vaccination village), 58% of marked dog deaths were due to hyena predation while 25% of deaths were due to sickness. Preliminary household questionnaire data from 2010 revealed that hyena sighting was prevalent in all villages. A majority of households (68% in control villages, 87% in vaccination) reported they saw hyenas on a daily basis, and this did not differ between villages (($F_{3,196}$=1.5, p=0.2).

DISCUSSION AND FUTURE DIRECTIONS

Higher female FCM concentrations may indicate stress associated with reproduction and/or competing with males for food in the households. While FCM does not appear to be affected by body condition score, we will be evaluating other factors that may affect stress. These factors include number of other dogs in household (competition), feeding regime by owners, presence of wounds, and reproductive status. We will continue to collect fecal samples to further characterize the FCM of free-roaming domestic dogs near Serengeti National Park.

Presently we have completed household revisits for Buyubi (August 2011), Nangale

(September 2011), and Sanungu (October-November) villages. All households, with the exception of 2 which moved away, have been revisited. We have collected life history data of 721 of the 2010 marked dogs and have marked 215 new dogs. We will continue to follow these dog life histories and collect household questionnaires in 2012 and 2013.

The preliminary data from this field season suggest while death due to sickness decreases in vaccination villages, hyena predation may be a significant limit to population growth. Data will be further analyzed after the 2011 field season to compare survivorship in vaccination and non-vaccination villages, between vaccinated and unvaccinated dogs and other variables.

We recently initiated a pilot study incorporating remote photography to validate and quantify wildlife presence in the study villages using six camera traps positioned throughout the villages. We are coordinating with local village leaders to obtain a village census (number of people and dogs) and household distribution within the village to determine future camera placement.

Incorporating remote photography into this project will provide information about hyena (Crocuta crocuta), black-backedjackal (Canis mesomelas), other small and medium sized mammal presence in the villages, domestic dog movements outside of the households, and potential domestic dog and wildlife interactions. Such information could reveal important aspects of domestic dog population dynamics and environmental conditions (presence of wildlife) that we are unable to observe during household visits. Finally, village spatial distribution information will aid with the evaluation of vaccination coverage and planning of future vaccination campaigns.

Implications

This research is significant in that it provides critical data for the Serengeti Health Initiative, Alliance for Rabies Control, and Tanzanian officials. This data is imperative if vaccination programs are to continue particularly as understanding population dynamics will reveal what proportion of the domestic dog population to target for vaccination. Mitigating rabies risk and exposure with dog vaccination campaigns would eliminate human death due to rabies and the severe financial burden of post exposure treatment, wound treatment and livestock loss.

This research has considerable implications for wildlife conservation in Serengeti National Park and potentially other areas because managing dog populations may decrease devastating disease outbreaks in wildlife populations. Maintaining a diverse and a healthy wildlife population has economic ramifications because the wildlife of

Serengeti National Park is an integral part of the tourism industry in Tanzania.

Free-roaming dogs live in a very dynamic and complex system where they are affected by humans, disease and wildlife. While domestic dogs have been extensively studied from a variety of angles, there are still significant gaps in our understanding of dog ecology in areas where dogs exist in the interface of humans and wildlife. This research will provide this much needed information with broad applications for dog population management, wildlife conservation and public health.

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EFFECTS OF ELEPHANT DAMAGE TO LONDROSI FOREST PLANTATION, WEST KILIMANJARO

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ABSTRACT

The present study was carried out to assess the damage effects of elephants on the tree vegetation (Pine (Pinus patula) and Cypress (Cupressus lusitanica)) of Londrosi Forest Plantation. The study area was divided into three (high risky, medium risky and low risky) blocks depending on the exposure risky to elephants. The block measurements were set at 70 by 50 metres which contained 875 trees plants each. The methodology entailed observation, counting and classifying tree damage into eight established categories. The results found elephants damage to occur mostly on tree aged between 8-12 years old. Pinus patula appeared to be the most damaged tree as compared to Cupressus lusitanica. The dominant damage category observed was breaking of trees from their base and pushover while other damage categories occurred less often. The damaged trees appeared not to re-sprout and contributed a significant loss (estimated at a minimum of 2 million Tanzanian shillings per season) to the plantation. The deterrent measures applied to protect tree vegetations from elephant raids appear not to be effective. The study propose carefully selection and planting other tree species not preferred by elephants on risky zones but have similar market values as Pinus patula and Cupressus lusitanica.

Key words: *Loxodanta africana, Plantation Forest, Human-elephant conflict.*

INTRODUCTION

African Elephant (Loxodonta africana) is the largest land mammal inhabited most of the continental Africa south of Sahara desert (Estes, 1997). These animals show great variation in feeding pattern depending largely on the quality and quantity of available feeds and also due to physiological or behavioral status prevailing at the particular moment (Cordon et al., 2011). Elephant strip barks of trees, push over trees and sometimes uproot entire tree to access forage (Chiza pers. observation, 2011). In so doing, they modify the entire vegetation structure where they live (Meredith, 2001). Elephant together with Impala are known to have more broad diet than practically other herbivores as they are intermediate (mix) feeders (Kos et al., 2012). The proportions and kinds of forage eaten vary seasonally and according to availability and they tend to select the most nutritious and palatable plants available (Estes, 1997). Like other mixed feeders, elephants tend to concentrate on grasses and herbs in the rain season and on the woody plants in the dry season. Seasonality is one among many factors determining elephants' movement outside the protected area (Meredith, 2001).

Despite the beneficial effects of elephants (trails making, wells digging and bringing food within reach of small browsers) their destructive behaviour of trees has been a problem in several African parks (Estes, 1997).

Elephants require large home range for their survivor (Santra et al., 2008). The ranging pattern is determined by availability of water, food and other resources. Resources distribution is not restricted in protected areas only so do the ranging pattern. Kilimanjaro National Park is not different from this fact. It is therefore common to find elephants ranging outside the park into adjacent landscapes including Londrosi Forest Plantation. In these places elephants tend to feed on available feed plants including plantation trees hence modifying their growth. The consequences are the reduction of quality and quantity of tree products from the plantation. Despite the fact that elephants regularly range outside the park into Londrosi Forest Plantation, no comprehensive study have previously been conducted on the effects of elephant on tree damage. This study aims at assessing the impact of elephants on tree in Londrosi Forest Plantation in West Kilimanjaro. Specifically, the study intended (i) to determine the extent of damages caused by elephants to trees (ii) determine the age at which trees are much more vulnerable to elephant damages and (iii) to assess the effectiveness of methods used by the Forest Plantation Management to prevent elephants' damages to trees. It is expected that, the findings from the present study will provide the benchmark information which will assist in the design of the control strategies to minimize the effects of elephants on the plantation.

STUDY METHODS

Description of the study area

The study was conducted at Londrosi Forest Plantation in West Kilimanjaro (Figure 1). West Kilimanjaro is an area in Siha District which was upgraded in 2005 to an independent district by the government of Tanzania. A principal town of Siha District is Sanya Juu whose area is around 1,158km^2. Siha District is boarded to South and West by Arusha Region, to the North by Kenya and to the East by Hai District (Adventure Aid Report, 2007).

Vegetation

The vegetation of Londrosi area is montane forest vegetation which changes gradually towards an alpine type as the altitude increases towards Mount Kilimanjaro (The Travel Guide, 2011).

Climate

Temperature in the study area fluctuates from 16.30 C to 30.10 C depending on the season and prevailing weather condition. Mean precipitation is 2300 mm per year.

The rainfall is bimodal, that is, there are two rain seasons per year whereby long rains start on March and extend as far as May and short rains between October and January. Between August and February, the area experiences warm period while cold periods are between June and July (The Travel Guide, 2011).

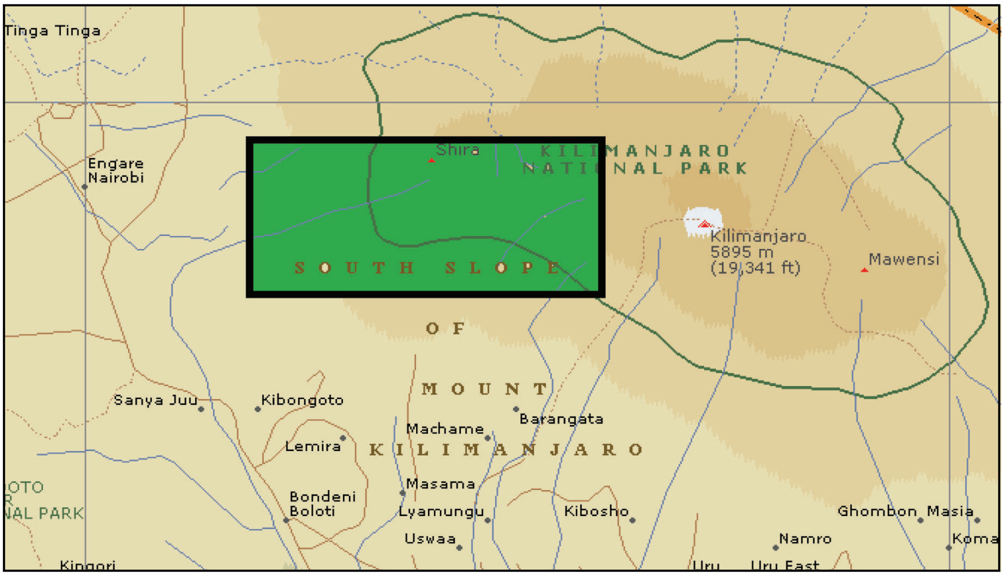

Figure 1: Map of Kilimanjaro National Park showing the study area marked green.

Sampling design and data collection

The study was purposely divided into three blocks (quadrants) of (70 by 50) m2. The block placement depended on the level of exposure to elephant raids. One block was located on the high risky area, followed by medium risky area and finally on the less risky area. In each block the trees damaged by elephants was counted and their ages determined. Damage was assessed and classified based on the damage categories described by Swart (1995) as (i) Tree not damaged (ii) Less than 50% of the circumference of the bark is removed (iii) Fifty percent to less than a hundred percent (50% - < 100%) of the circumference of the bark is removed (iv) Tree is ring backed (v) Branches removed a) Ten to twenty five percent (10-25%) (b) Greater than twenty five percent to fifty percent (>25-50%) (c) Greater than fifty percent to seventy five percent (>50-75%) and (d) Greater than seventy five percent to a hundred percent (>75-100%) (vi) Branches broken (a) Ten to twenty five percent (10-25%) (b) Greater than twenty five percent to fifty percent (>25-50%), (c) Greater than fifty percent to seventy five percent (>50-75%) and (d) Greater than seventy five percent to a hundred percent (>75-100%) (Vii) Tree basely broken (a) Tree dead and (b) Tree alive (viii) Tree uprooted (a) Tree dead and (b) Tree alive (ix) Cause of death unknown.
(Damage because of bush fire; age; disease; Insects; drought or other animals.
(xi) Tree pushed without damages inflicted by elephant a)Tree dead and b) Tree alive

Secondary Data was obtained from the Management of West Kilimanjaro Forest Plantation and from available literatures such as journals, newspaper and other documented materials related to this study.

Data analysis

The information collected were summarized in excel and descriptive statistical analysis performed for each block and results presented in form of table and figures.

RESULTS AND DISCUSSION

Extent of damages caused by elephants to trees

The present study showed a number of damage categories caused by elephants to occur in Londrosi Forest Plantation (Table 1). A total of 5250 trees were counted in the three blocks designed according to elephant damage exposure. Two types of tree plants, Pinus patula and Cupressus lusitanica are grown on the forest. Elephants caused 4.5%, (n = 238) damage on the total tree counted. Counts of the trees damaged shows that, Pinus sp was the most damaged tree in the forest (n = 202) as compared to Cupressus lusitanica (n = 36). The dominant damage category observed was basely broken tree followed by tree push over without any signs of damages, tree uprooting and various degree of tree debarking (Table 1). Small proportion of trees had their damages not directly linked to elephant raids (Table 1). The details for each damage category are outlined below;

Trees basely broken

Trees basely broken were found to contribute highly on the total trees damaged by elephants (Figure 2). Out of 238 damaged trees, 53.4% (n = 127) were basely broken. Pinus patula were more affected (n = 117) through this type of damage than Cupressus lusitanica (n = 10). Trees basely broken were left to dry and taken for firewood by the workers of West Kilimanjaro Forest Plantation.

Trees pushed

Out of 238 damaged trees, 21% (n = 50) were pushed. Forty three (43) of the pushed trees were Pinus patula which is approximately 86% of the pushed trees (Figure 3). The pushed trees are cut down and left to dry for being used as firewood because they won't grow in a normal way as supposed and usually die due to poor root developments due to exposure.

Trees debarked

Another type of damage classification is tree debarking. Debarking was either <50% of the circumference removed, or range between >50% to <100% of the circumference being removed or the tree was completely ring barked. It was observed that 6 trees had <50% of their circumference removed, 13 trees had >50% to <100% of circumference removed and 5 trees were ring barked making a total of 24 debarked trees. Thus, the debarked trees contributed to about 10% of the total trees damaged by elephants. <50% of the circumference removed contributed 25% of the trees debarked while >50% to <100% contributed about 54% of debarked trees and ring barked trees contributed about 20.8% of the trees debarked. Species wise, about 62.5% (n = 15) of debarked trees were Pinus patula and the rest 37.5% (n = 9) were Cupressus lusitanica. The roots of the debarked trees are the ultimate cause of trees death since dissolved sugar and nutrients produced on the leaves do not reach the root zone. Figure 4 below shows the drying tree as a result of debarking.

Figure 2: Pinus patula tree broken by elephants at its base in Londrosi Forest.

Figure 3: A Pinus patula tree pushed by elephants in Londrosi Forest.

Figure 4: A debarked Cupressus lusitanica tree in Londrosi Forest

Trees uprooted

Trees uprooted was another criteria used in classification of damages (Figure 5). It was found that 7.5% (n = 18) of the total trees (n = 238) were uprooted. About 88.6% (n = 16) of uprooted trees were Pinus patula. Trees uprooted are left to dry and taken for firewood.

Figure 5: Uprooted of Pinus patula tree in Londrosi Forest.

Trees with broken or removed branches

Another type of damage classification was branches broken or removed. Observation has showed that there was no tree with broken or removed branch. This suggests that elephants do not feed on the branches of these two species (Pinus patula and Cupressus lusitanica).

Tree whose damage causes were unknown

During the present study 8% (n = 19) of the observed trees damaged were not directly related to elephant activities (Figure 6 & 7). About 58% of these trees were Pinus patula and 42% (n = 11) were Cupressus lusitanica.

Figure 6: A fallen Pinus patula tree with its branch not broken or eaten by elephant in Londrosi Forest.

Figure 7: A damaged Cupressus lusitanica tree but the cause of the problem was not linked directly to elephants.

Age of trees mostly damaged

It was found that most of the damaged trees (83%, n = 198) by elephants ranged between 8 - 12 years and the rest were below the age of 8 years. The ages were determined by reading the labels put in each particular block.

Effectiveness of the method used in controlling elephants

The use of guns to scare elephants is the sole method used by the Forest Management to control elephants. The guns are fired in air and the sound produced is supposed to scares elephants so that they go back to the Park. However, with time, the effectiveness of this method seems to decrease and elephants are reported to get familiar with the technique. Moreover, most of the elephant's raiding activities occur at night and thus complicates the intervention process.

Apart from the guns used by the Forest Management to control elephants, people performing small scale agriculture have their ways to control elephants against crop raiding which in turn offer protection to the forest plantations from elephants' damage. One of such methods is guarding. In this method people stay vigilant in their farms during night and use fire to keep elephants away from their farms. Because farming is within the plantation (Taungya system) people guarding their farm indirectly do the same to the plantation. This method provides partial protection to the plantation as guarding is performed only on the areas where there are crops.

Another method practiced by farmers was the use of a cassette's tape elements to scare elephants. A tape element is removed from cassette and the thin string tied around the farms. When the wind blows, the tape element produces a whistle sounds which causes disturbance to elephants and discourage them from attacking such farms. The method is however, not very effective as it depends much on the wind which is not guaranteed every day. Like disturbance shooting, elephants also do get used to such noise and eventually attack the farm which they previously avoided.

Estimated loss

Most of the trees in Kilimanjaro Forest Plantation have a volume ranging from 1 to 1.5 cm3 when they are mature and ready to harvest. A tree of 1 to 1.5 cm3 costs about 8,000/= to 10,000/= Tanzanian shillings making an average of 9,000/= Tanzanian shillings. There were 6 blocks and each is 70 m by 50 m (3,500 m2). If 1 bock is equal to 3,500 m2 then 6 blocks will have an area of 21,000 m2 which is equal to 0.021 km2. According to observation summarized in Table 1, in a 0.021 km2 there are 238 damaged trees. If one tree costs an average of 9,000/= Tanzanian shillings then 238 trees cost 2,142,000/= Tanzanian shillings. So in every 0.021 km2 elephants cause damages estimated to cost a minimum of 2,142,000/= Tanzanian Shillings every season they enter and raid the Forest Plantation.

Possible reasons for elephants to enter the Forest Plantation

Reasons for elephants to enter the forest plantation can be attributed to several factors. These factors include hard edged interface between the park and plantation, encroachment of the park area by the plantation, Taungya system (mixing of small scale agriculture with Forest Plantation) and possibly plantation established on elephant movement corridor.

Starting with plantation-park hard edged interface; it was observed that there was no buffer zone to separate the plantation from the park. The forest plantation was directly connected to the park hence make it a continuous habitat for the elephants to cross into the plantation (Chiza pers. observation, 2011). It was also noted that, the current forest plantation was once a part of the National Park (Makamang'oko pers. communication, 2011). The transformation of a portion of the park to a forest was possibly done without a proper analysis and this could be very difficult to solve. The set plantation could be one of the important elephant's home range or dispersal area and thus why they normally enter the plantation.

It is known that, there is existence of assumed or unconfirmed corridors (Mpanduji, 2005). West Kilimanjaro Forest Plantation may be laid on the area which is an unconfirmed wildlife corridor thus why elephants' problem does not end.

Moreover, the inclusion of small scale agriculture within plantation (Taungya system) may attract elephants towards the plantation. This is because some of the crops grown within the plantation are preferred by elephants and therefore attract them towards the plantation. In Londrosi Forest Plantation crops grown that are preferred by elephants are carrots and maize. The reduction of available habitat within the historically occupied elephant range due to encroachment has led to an increase of elephants raiding crops (Linkie et al., 2004; Sitati et al, 2005 in Rood et al., 2008). In some cases, the total conversion of elephant habitat has left elephants residing in a landscape dominated by humans (Rood et al., 2008).

Trees most Damages by elephants

The counts for the damaged trees show that, pine (Pinus patula) (85%, n = 202 of the damaged trees) was more affected than cypress (Cupressus lusitanica) (15%, n = 36 of the damaged trees). This observation concurred with the previous study by (Afolayan, 1975) in West Kilimanjaro where Pinus patula schede suffered most damage caused by elephants).

The type of the damage caused a lot of trees death was a tree basely broken. This suggests that elephants prefer the tips of trees than any other part because trees basely broken were found without their tips. This may be due to tenderness of the tips compared to other parts. This can also be linked to the reason why branches were not damaged, may be because they are hard, thus elephants break the trees to get access to the tips.

The age of trees mostly affected was found to be between 8-12 years. The age stated may not reveal the truth because damaged young trees were removed and replaced by new trees so they were not counted.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Elephants observed to have impacts on the vegetation of Londrosi Forest Plantation and imposed a considerable cost by their damages on trees. The damages are more pronounced on Pinus patula (85%, n = 202) than on Cupressus lusitanica (15%, n = 36). A tree basely broken is a type of damage which contributed much to the death of trees. Moreover, it was observed that elephants' damages were not directed to the branches as there was no branch removed or broken down. Methods used by West Kilimanjaro Forest Management appear to be ineffective in controlling elephants from damaging trees.

Recommendations

i. The study recommend to the Kilimanjaro Forest Plantation Management not to rely on Cupressus lusitanica species in the areas prone to elephants' attack. Instead, other valuable trees of similar growth rate and market potentials but less preferred by elephants be identified and planted in such places.
ii. Dealing with problem elephants has been an issue in many inter-phase areas like Londrosi-KINAPA. In all these places where such problems exist, an integrated control programs are advised and in this case, the study recommend a modification of threat-deterrent barrier approach using locally available materials.
iii. The management of KINAPA should try to identify the reason(s) that compels elephants to leave the park and perform necessary interventions to minimize such movements by providing what the elephants are missing in the Park.
iv. There should be a negotiation between KINAPA and Forest Management to set an area which will act as a buffer zone to separate the park from forest plantation to reduce the incidences of elephants to enter the plantation.

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POPULATION STRUCTURE AND BODY CONDITIONS RELATED TO FEEDING BEHAVIOR OF YELLOW BABOONS AT MIKUMI NATIONAL PARK, TANZANIA

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ABSTRACT
Comparison on population structure and body condition score in relation to feeding behaviour was carried out for three known troops of yellow baboons (Papio cyanocephalus) at Mikumi National Park. The troops included (i) Mwanambogo - which obtain its feeds entirely in nature, (ii) Lyambangali - mostly using household garbage's around the park headquarters and (iii) Kikoboga - regularly found scavenging along the Dar es salaam-Iringa highway. In all these, troop size, sex, age and body condition score for each individual encountered was recorded. The body condition was scored as very bad, bad, moderate, good, very good and adipose or obese. During the study, a total of 176 baboons were observed and counted. Large troop size (n= 61, 34.7%) was observed for Lyambangali followed by Mwanambogo (n= 59, 33.5%) and Kikoboga (n= 56, 31.8%). Female to infant ratio was (6:1) for Mwanambogo, (4:1) for Kikoboga and (2:1) for Lyambangali troops. In terms of body condition scores, 85% (n =52) of Lyambangali troops scored very good as compared to about 75% (n =44) for Kikoboga and Mwanambogo. Household garbage' appears to supply sufficient feeds to Lyambangali troop as embodied by good body condition as well as small female to offspring ratio. The dependence on household and roadside garbage for Lyambangali and Mwanambogo troops is an emerging problem which is already a nuisance to the park residents as well as tourists. This behaviour is likely to spread easily to the neighboring villages of Doma, Mikumi, Maharaka and others where it can be very difficult to contain. The study recommends stringent protective measures to be developed and applied to prevent the aberrant behaviour that have started to develop in yellow baboons at Mikumi National Park.

Key words: *Mikumi National Park, Yellow Baboon, Behaviour.*

INTRODUCTION
Yellow baboons (Papio cynocephalus) have a diverse diet and can exploit a wide variety of feeds depending on the conditions of the particular season, availability and abundance. They spend approximately three-quarters of their time feeding or moving (Post, 1981). They are extremely selective in their foraging behaviour although

have a high diversity diet (Norton et al., 1987). However, during food scarcity, they become opportunistic eaters, thus can eat almost any food they come across with and are known by locals and tourists as being cheeky and stealing their food, but this behaviour is mainly aggravated by the bad habit of providing feed to them (Maples, 1976). Development of tarmac road bisecting Mikumi National Park have shown many shortcomings to the baboons including been feed by humans with man-made foods and accidental mortalities to groups of baboons. These developments has evolved into three baboon subpopulations depending on their ranging and feeding behaviour. Firstly, those which are always seen along the Doma-Mikumi main road waiting for food that dropped or provided to them by passengers travelling across the park. Secondly, those which are predominantly found on the living Quarters and the third subpopulations are those which do not occur in association with people or any man-made structures obtaining their daily feed in the wild. Baboons that are found along the road and human living premises appear to have constant supply of food and are likely to have great chances to reproduce and successfully raise their offspring as compared to the ones depending on the natural food availability which varies with season. It is assumed that, the group size and population structure for the Baboons using man-made structures will show a health and positive population trend as compared to those living freely in the wild. The study aimed at determining whether there are some differences in their population structure and body condition score for the baboons using man made structures to maximize their chances of getting foods and those which are using the natural occurring food in natural environment. The information obtained from this study will assist the park authority, wildlife conservationists, policy makers and development partners in creating awareness on the effects of artificial environment on the behaviour of wild animals.

Objectives

To assess the population structure and body condition scores of three subpopulations of Yellow Baboons at Mikumi National Park

Specific objectives

- To assess the group size and composition (age/sex) of baboons predominantly using man made structures and those that do not use them.
- To assess the body condition score of baboons predominantly using man made structures and those that do not use them.

MATERIALS AND METHODS

Study area

Mikumi National Park is located in Eastern Tanzania, north of the Selous game reserve between latitudes 7°00’-7°50’S and longitudes 37°00’-37°30’E, covering an area of about 3230 sq km, at an elevation of 550 - 1,257m.a.s.l. It was gazetted in 1964 and in 1975 the park extended its territory to share a border with the Selous Game reserve (Mercer, 1983). The park is bordered to the south by the Selous Game Reserve, the two areas forming a unique ecosystem (Selous-Mikumi ecosystem). Two other natural areas bordering the national park are the Udzungwa Mountains and Uluguru Mountains.

The park comprises of two major ecological zones, the grassland and wooded savannah of the extensive Mkata River flood plain with hardpan ridges and black cotton soil pans with upland seasonal swamplands hilly country to the east. The western and southern part is covered with miombo vegetation.

Climate

The park has the bimodal rain season, characterized by short rains in October to early November, followed by long rains lasting for five months, although the rainfall pattern is very unpredictable. Rainfall varies with annual rainfall of 500 mm at park headquarters and 625 mm at Chamgore waterhole (25 km to the north) and over 1,000 mm on upper hills. The wet season extends from November to May, March and April being the wettest months (Garden, 2011). However there is always a definitive dry period between January and February. The wet months are associated with a hot humid weather, where temperatures reach up to 30oC. Dry months are always cooler with temperatures between 20oC and 25oC. Annual average temperature is 25.5 oC (TANAPA, 2004).

Data Collection Methods

To determine the population structure and body condition scores, the main road traversing the park (Kikoboga) was used as the sampling block for baboon subpopulation predominantly using road for their survival. The second sampling block was designed along the headquater and residential areas (Lyambangali) to represent the subpopulation of baboons depending on household refusal or garbages as their survival stratergy and the third block was placed away to Mwanambogo circuit/areas known to harbor free ranging baboons. In all blocks, observations were carried out early in the morning as well as late in the evening when the baboons were active.

The observer used to drive a car in search of baboons. When observed, the car was stopped if they were along the road or driven towards them when they are offload for closer observation The following information were recorded: Number of individuals encountered, sex, age estimation of each individual (number of infants, juveniles, sub adults and adults), estimate of body condition of individuals in a group (i.e normal,obese and/or debilitated as described by Knauf, 2010) (Table 1) and other observed malformation (like broken arm etc).

Secondary datawere collected from repositories from the Sokoine University of Agriculture National Library (SNAL) and from other research departments within and outside the University.

Table 1: Body condition scoring creteria (Sourced from Knauf. S. 2010)

Very bad condition	Absolutely no subcateneous fat, severe muscular weakness, skeletal system is prominent, cachexia
Bad condition	Same as very bad condition but with almost no subcutaneous fat and moderate muscular weakness
Moderate condition	Underweight and with only a small percentage of subcutaneous fat but still in acceptable condition
Good condition	Physiological body mass, normal subcutaneous fat, muscular system well developed
Very good condition	In between good and adipose but still physiologic
Adipose	Abnormal subcutaneous fat, body weight above normal, skeletal system not visible

Data Analysis

Qualitative and quantitative analysis of data was carried out.. Quantitative data on group size, composition and age classes and qualitative data on body condition scores were both compiled and summarized using Excel statistical packages for Windows and the results are summarized and presented. .

RESULTS AND DISCUSSION

Body Condition Score

During the study a total of 179 baboons were observed, many of them were from the Lyambangali subpopulation (Plate 1). Fifty four percent (54%), of the total baboons observed were in the category of good while 22% on the very good body conditions scores. A small proportions of 16.7%, 2.2% and 1.7% showed moderate body condition score, other abnormalities and adipose deposition respectively (Table 2). Examination of individual sub-populations revealed a difference in the body condition scores between the Lyambangali and the rest of the sub-populations where the Lyambangali sub-populations showed 85% of her members to have between very good body condition score. The Kikoboga and Mwanambogo sub-populations showed 75.5% and 74.6% of their population to slightly between good and very good body condition score respectively (Table 2). Large number of individuals that had a moderate body condition score were observed from Mwanambogo (Table 2).

The observed differences in body condition scores in all three sub-populations found at Mikumi National Park were related to accessibility of feed resources. It was observed that groups that utilized the park headquarters have a reliable feed source than those utilized road and natural habitats. This is ascribed to the extra feed sources scavenged from household garbage and leftovers. Small aliments were observed from the Lyambangali and Kikoboga sub populations. This is attributed by their ranging behaviors. At times, these groups spend feeding on roads and garbage pits and thus exposed to accidents and predation.

Plate1 .The Lyambangali's Baboon Sub-population which utilize residential and Park Headquarter as their ranging areas.

Habituation

The baboons sub-population that inhabit the headquarter (Lyambangali) and those which roam along the highway (Kikoboga) were accustomed to people who provided them with some artificial food materials (Plate 1 & 2). The dependence to artificial feed supply seem to have changed their behaviour to the extent of being reluctant to look for their own food supply in the wild, instead kept on waiting along the highway or around human settlements for an opportunity. To them, this behaviour ensure availability of nutritious supplement diet as compared to the ones (Mwanambogo sub-population) depending only on natural feeds obtained from the wild.

This is depicted on good body condition score observed for Lyambangali and Kikoboga sub populations. Improved nutrition's also enhanced the cycling to females and many appeared to be on heat during the study period as exemplified by several encounters of mating events (Plate 3) as compared to Mwanambogo baboons sub population.

Table 2: Number of individuals for each category indicating body condition score for the different subpopulations of Yellow baboons found at Mikumi National Park.

BABOON'S SUBPOPULATION	BODY CONDITION SCORE							
	VERY BAD CONDITION	BAD CONDTION	MODERATE CONDITION	GOOD CONDITION	VERY GOOD CONDITION	ADIPOSE	OTHER ABNORMALITIES	TOTAL
LYABANGALI	0	0	6	36	16	1	2	61
KIKOBOGA	0	0	9	30	11	2	2	55
MWANAMBOGO	0	0	15	31	13	0	0	59
GRAND TOTAL	0	0	30	97	40	3	4	179

Plate 2: Shows the Kikoboga Baboon Sub-Population on top of the car searching for artificial foods from the researchers' car

Population structure

The present study indicates an adequate representation of all age groups on each sub population (Table 3). However, it has to be noted that, the date shown here represent only the baboons that were observed and classified. It was difficult to observe and classify all the baboons encountered due to presence of tall grasses which made possible for them to hide and obscure observation. It was easily to identify infants but not the juveniles and the sub adults.

Plate 3. The Kikoboga baboon sup-population mating along the Dar Es Salaam- Iringa high way. Many such incidences were observed along the road and Lyambangali sub-populations, this has resulted into accidents and increased road baboon road killings.

The Lyambangali sub-population represented the highest troop size followed by Mwanambogo and Kikoboga sub-population respectively. The presence of infants also showed some differences between the study populations. The Lyambangali subpopulations showed higher percentage (4.55%) of infants counted as compared to Kikoboga (2.27%) and Mwanambogo (1.70%) sub-populations. Furthermore, a decrease in the ratio of females to infants (F:I) was observed (Table 3) from Mwanambogo (6.02:1) to Lyambangali subpopulation (2.37:1). This implies most of the females in Lyambangali sub populations had infants during the research period as compared to other sub-populations observed.

Several factors could have been contributed to these observed differences and may includes; Greater probability of getting food to the baboons occupying Lyambangali area. This span from natural sources to garbage from the headquarter dwellers. Those which dwell away from man made structures depend entirely on nature. Poor cycling and predation may be another factor that contributes to the presence of low percentages of infants in Mwanambogo sub-populations. Other possible explanation to this might be the capability of female baboons to raise their infants to the mature age by providing them with adequate food and utilizing some artificial structures to protect their young from predation.

Table3: Showing the number in brackets and percentage of age categories of the three Baboon Sup-Populations at Mikumi National Park

BABOON'S SUB-POPULATION	Age category (%)							
	No of infants	No of juveniles	No of sub adults	No of adults	No of females	No of males	Troop size	Female/infant (F:I)
LYABANGALI	(8) 4.55	(16) 9.09	(10) 5.68	(27) 15.34	(16) 10.80	(8) 4.55	(61) 34.66	2.37:1
KIKOBOGA	(4) 2.27	(27) 15.34	(4) 2.27	(21) 11.93	(17) 9.66	(4) 2.27	(56) 31.82	4.26:1
MWANAMBOGO	(3) 1.70	(25) 14.20	(6) 3.35	(25) 14.20	(18) 10.23	(7) 3.98	(59) 33.52	6.02:1
PERCENTAGE TOTAL	(15) 8.52	(68) 38.64	(66) 11.36	(20) 37.50	(54) 30.68	(19) 10.80	(176) 100	4.22:1

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study revealed that, a behavioral change was higly influenced by development of artificial feeding strategies for the Lyambangali and Kikoboga Sub populations. The artificial foods obtained appear to improve the survival of the subpopulations that benefit from it. This is signified by the differences on troop size and female-infant ratio from the sub population that depend generally on the natural food availability and the ones obtaining additional food from roadside leftovers and household garbage. Improved supply of nutritious food enhanced the reproductive capability and improved the health status of the Lyambangali more that the other two (Kikoboga) and (Mwanambogo) sub-populations.

Recommendation

This study was of limited scope in terms of the number of days spent in the field observing baboons and covered a short period of rain season only. It did not take into account the dry season. However, the study observed a change on the feeding behaviour of the three sub-populations from the natural conditions towards dependency on garbage's thrown by passengers to household leftovers. Interesting results could be obtained by observing same troops during the dry season and on a long term basis. The dependency on artificial feeds should not be welcomed for the naturally occurring baboons as these can turn them into menace. There is a possibility of the troops using the road to expand their range to the nearby villages of Doma and Mikumi , this will increase a possibility of having more human-baboon coflicts

The study recommends that, park authority should design an appropriate education programs that will encourage passengers and drivers crossing the park not to feed the baboon or throw leftovers by the roads. Inside the park, the disposal facilities should be strengthened as to date baboons appear to cross the barriers set and fed on leftovers.

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ASSESSMENT OF THE POPULATION STATUS OF THE ELUSIVE BIRD SPECIES SOKOKE PIPIT (*Anthus sokokensis*) in ZARANINGE COASTAL FOREST, TANZANIAN.

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ABSTRACT
The outstanding importance of Tanzanian coastal forests for biodiversity conservation to the country is well recognized, however this is not adequately reflected in the protection efforts allocated to these forests. While mountain forests have been widely recognized and put under adequate protection, coastal forests which are much smaller have only been recently recognized as needing similar attention. Most of these forests have already been shattered through encroachment, selective logging, charcoal burning, agriculture and pole cutting owing to breakdown of traditional systems of conservation. Using line transects and mist nets; we studied the population status of an endangered and elusive bird species, the Sokoke Pipit (Anthus sokokensis) in the Zaraninge forest from August 2010 to August 2011. Following surveys made along forest edge and the forest core, eight individuals were observed in five encounters. Analysis using the DISTANCE program demonstrates that the population of Sokoke pipit is very low in the forest (1.6 Individuals/km2). Furthermore, our results suggest that, the low population of this species is associated with human disturbance as the bird tends to be very shy and highly sensitive to intrusion. We recommend training communities in conservation, and supporting them with tools and skills; increasing law enforcement and monitoring of biodiversity and threats is important for long term survival of the Sokoke pipit.

Key words: *Population status, endangered species, Sokoke pipit and Zaraninge Forest*

INTRODUCTION
Forest clearance and degradation is the single most important threat to the birds of Africa and its related islands (Collar and Stuart, 1985). This forest destruction resulting from extensive human encroachment led to the loss of important bird habitats including breeding and nesting sites. East African coastal forests have suffered the same catastrophe, despite being known for their support of many genera of endemic plants and animals. For instance it is believed that up to six bird species, two mammals, six reptiles, five amphibians and at least fifty invertebrates and hundreds of vascular plants are endemic to coastal forests of Kenya and Tanzania (Sheil, 1992; Burgess

et al, 1993). Hence these forests should be made high priority for conservation of biodiversity. Moreover, within East African coastal forests, many individual forests are known to accommodate a number of plants and animals endemic to those particular forests or only known in a few other sites (Burgess et al, 1993). For instance, the Zaraninge forest with an area of 174km2 is reported to harbour four endemic plant species and one invertebrate (Sheil and Burgess, 1990; Burgess et al, 1993). This same forest also harbours more than 70 species of birds (Burgess et al., 1991; Faldborg et al., 1991), of which ten are classified as globally scarce giving the forest international recognition (Collar and Stuart, 1985). Among the ten globally scarce bird species, the elusive Sokoke pipit (Anthus sokokensis) has been classified as endangered by the IUCN (BirdLife International, 2012).

However, as a result of the breakdown of traditional systems of conservation, most of East Africa's coastal forests have already been shattered through encroachment, selective logging, charcoal burning, agriculture and pole cutting. Those which survived this destruction exist only as forest patches of the previously continuous forest. Among them is Zaraninge Forest in Bagamoyo. This forest is one of the remnants of the once much more extensive forest coverage of the Zanzibar-Inhambane Phytochoria vegetation zone (White, 1983; Clarke, 2000; Linder et al, 2005). It is characterised by closed canopy vegetation (particularly on the plateau), woodland mosaic and thicket scrub vegetation with dry and moist habitat (Mligo et al, 2009). Despite this, the forest is highly fragmented and has vegetation communities that support a wide diversity of animal species. Moreover, it's flora and fauna like in many other coastal forests has been understudied and as a result, little is known about the effects of such factors as human encroachment and habitat destruction on the ecology of animal and plant species present, especially forest dependant species such as Sokoke pipit.

The Sokoke Pipit (Anthus sokokensis) is a bird species in the Motacillidae family. It has been classified by the IUCN as an endangered species due to its very small range, within which the total area of its forest habitat is declining owing to clearance for cultivation and intensive charcoal production (Keith et al, 1992). In the past, the Sokoke pipit was known to occur in most east African Coastal forests. However, following the degradation of its natural habitat, increased human activities such as forest clearing for agriculture and tree cutting for timber and charcoal production, its occurrence has now been restricted to a few East African Coastal forests in Kenya and Tanzania, Zaraninge Forest being the only forest its occurrence has being currently recorded in Tanzania so far (Burgess et al., 2000). Unlike their counterparts in Arabu Sokoke in Kenya, the population of Sokoke pipit in Tanzania is currently uncertain. However, it has been suspected that with extensive destruction of coastal forests, the population of Sokoke pipit in Tanzania is declining along with its habitat and probably the has already gone extinct in some forests where they were previously known to occur, such as Vikindu and Pugu-Kazimzumbwe forests (Bird Life, 2011).

Moreover, a threat to the populations' status in Tanzania is also contributed by lack of knowledge on their ecology. For instance, since Sokoke pipits were first observed in the Zaraninge forest in 1990 by Neil Burgess and his team, no study has been conducted to determine their ecological adaptability in these remnants of east African coastal forests. Lack of such study in such an unstable habitat is truly worried, as the Sokoke pipit are known to be very sensitive to changes in their habitat and environment an can be compared to the canary in a mine (Byamungu et al, unpublished). Canaries (Serinus spp) were used in the mining of coal to detect any poisonous gases, miners would carry a captive canary into a mine as long as the canary kept singing, miners were safe (Byamungu et al., unpublished). For this matter, Sokoke pipits are considered excellent indicators for examining forest health. Therefore, this study was designed to determine the distribution and abundance of the Sokoke pipit in the Zaraninge forest, and therefore to advocate their population status in this forest in general. Thus, the information that results from this study is important especially in explaining the impact of forest destruction on avifauna composition and other forest dependant species.

MATERIAL AND METHODS

Description of the study area

The study was carried out in Zaraninge Forest (also known as Kiono), which is located in the Bagamoyo District, Coastal region in Tanzania (Clarke & Dickson, 1995). Zaraninge forest is found between latitudes 6º 4´-6 º 13´S and 38 º 35´- 38 º 42´ E (Clarke & Dickson, 1995). However, data were collected in the plateau part of the forest (cf.21 km2), rising between 100 to 300 m above the Saadani coastal plain, (figure 1). The raised plateau forms a source of small seasonal rivers draining to the Wami River and into the Indian Ocean (Mligo et al, 2009). These seasonal rivers are the major sources of water for the surrounding villages, wildlife and pastoralists.

The climate of Zaraninge Forest is monsoonal and is characterised by high temperatures and humidity in the dry and rainy seasonal respectively. The average annual rainfall is below 1000 mm per year (Clarke & Dickson, 1995). The rainy season starts from March to June followed by relatively cool season between June and August, and the short rains between September and November, thus bimodal (Burgess et al, 2000). However, the pattern of annual rainfall in the coastal forest ecosystems has drastically changed over the last ten years (Burgess et al, 2000). In collecting data for the determination of population status of Sokoke pipits in Zaraninge forest, two types of data collection techniques as described below were used; line transects for census data and circular plot for habitat use (which is described in another paper and project report (Byamungu et al in prep).

Data collection

In collecting data for the determination of population status of Sokoke pipits in Zaraninge forest, two types of data collection techniques as described below were

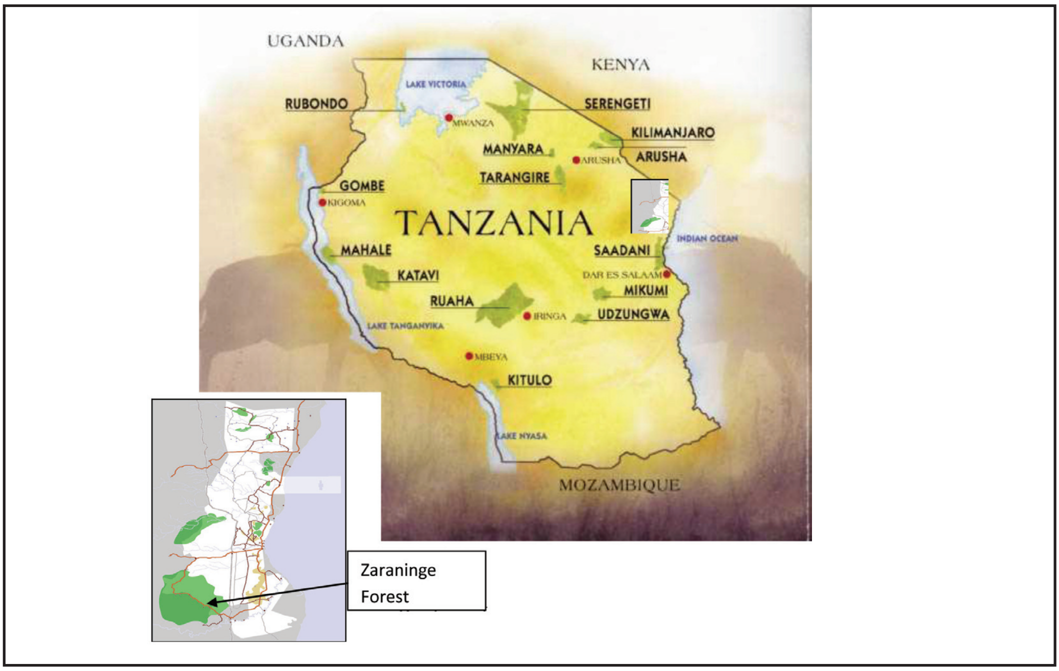

Fig 1: Map of Tanzania showing Position of Saadani National Park and the Zaraninge Forest Reserve

used; line transects for census data and circular plot for habitat use (which is described in another paper and project report (Byamungu et al in prep).

Line Transect count

Line transect was used for counting birds for the purpose of estimating the population density in the area (Bibby et al., 2000; Marrison, et al., 2001). The study area was stratified into different vegetation types and landforms (Marrison, et al., 2001; Sutherland, 1996). In this study two main strata were identified; forest edge and forest core. Four straight transects ranging from 400 to 500 m long were established in each stratum. Data collection spanned over three month, each transect was surveyed for three consecutive days each month. Observers walked along the transect recorded all birds that were seen or heard. On encountering the study species, various information such as sex, perpendicular distance from the line transects and positions of birds in transect were recorded using GPS. All counts were conducted before 10.00 am, thereafter stopped and resumed after 16.00 pm.). The maximum effective distance for the transect counts was estimated to be 10 metres either side of transect. In addition to the line transect playback recordings and mist nets were used to increase the chances of encountering the study species.

Habitat data collection

In addition to occurrence data, we also collected data on the habitat association of birds within circular plots of 15m diameter placed along transects at each bird sighting was recorded. The following variables were at each position where individual birds were sighted following Dallimer and King, (2008): Number of trees making up canopy (canopy count); Percentage canopy cover estimated by eye (canopy cover); Maximum height of canopy (canopy height); Average number of stems in three 1m-radius circles (ground cover); Presence of fruiting/flowering trees; Abundance of climbers and epiphytes; Inclination of terrain (slope) and Ridge position (0 – valley floor to 5 – ridge top).

Data analysis

Species population status was determined in terms of abundance of individuals estimated from species density data. This analysis was carried using DISTANCE software (Thomas et al. 1998). Analysis of variance (ANOVA) was used to determine which habitat variables influenced Sokoke pipit habitat preference (Bonnington et al., 2007).

RESULTS

A total of fifty six (56) surveys covered a total length of 15km along established line transects were conducted to determine the distribution and abundance of Sokoke pipit in two habitats; forest edge and forest core in the Zaraninge forest reserve. Eight (8) indivuals were observed in five (5) successful encounters of Sokoke pipit for the entire study period. While analysis using Distance programme showed the probability of detection was high (76.7%), the encounter rate was lower 0.26 indivuals/km (Table 1). With such an encounter rate, the population of the Sokoke pipit within a plateau segment of Zaraninge forest a (cf.21 km2) is estimated to be 34 individuals with a density of 1.6 individuals/ km2 (Table 2).

Table 1: Summary encounter rate of Sokoke Pipit in Zaraninge Forest, where n= number of observed objects (single or clusters of animals); L= total length of transect line where individuals where encountered; K= Line Transect effort

Table 1: Summary encounter rate of Sokoke Pipit in Zaraninge Forest, where n= number of observed objects (single or clusters of animals); L= total length of transect line where individuals where encountered; K= Line Transect effort

	Estimate	% CV	DF	95% Confidence Interval
N	8.000			
K	6.000			
L	30000			
n/L	0-2666	15.81	5.000	0-17805E-02 0-39939E-02

Table 2: show Sokoke Pipit abundance in the Zaraninge Forest, D= estimate of density of animals, N= estimate of number of animals in specified area

Parameter	Point Estimate	Standard Error	Percentage Coef of Variation	95% Confidence Interval	
D	1.6334	0.53511	32.76	0.79495	3.3561
N	34.000	11.139	32.76	17.000	70.000

DISCUSSION

Bird Life International places the Tanzanian population of Sokoke Pipit in the range band for 10,000-19,999 individuals. With this population estimate, if we consider IUCN criteria C (1 and 2a, 2b) for endangered species, that "population will be considered endangered if, population size estimated to number fewer than 2500 mature individuals and either: 1. An estimated continuing decline of at least 20% within five years or two generations, whichever is longer, (up to a maximum of 100 years in the future) OR 2. A continuing decline, observed, projected, or inferred, in numbers of mature individuals. Then the Sokoke pipits population in Tanzania is nowhere near endangered status, however we cannot tell with certainty as the population band given by BirdLife only qualifies for criteria C, and with lack of study of the Sokoke pipit, there is no available evidence for criteria C 1and C2a and C2b.

However, from our analysis, the total number of Sokoke pipits in Zaraninge Forest is estimated to be around 34 individuals. Currently in Tanzania most of the sites that have been known to accommodate Sokoke pipit has been destructed due to human disturbance for instance, there is practically no forest remaining at Vikindu Forest Reserve due to intensive charcoal burning and cutting (Bird Life, 2011). Moreover, there is very little forest remaining in the Pugu-Kazimzumbwe forest due to intensive charcoal burning and cutting for building materials (Bird Life, 2011). These two forests plus Ruvu forests were known for their rich distribution of Sokoke pipit, but now it is believed that, population of Sokoke pipits in those forests has been greatly reduced if not perished with their habitats (Mlingwa per com). Sokoke pipits are strictly forest dependant birds, shy and very sensitive to habitat disturbance (Burgess, 2000). With these facts, the estimated Sokoke pipit's population in the Zaraninge forest is the only currently known population of Sokoke pipit in Tanzania.

Therefore, according to Mace and Lande (1991), criteria for assigning conservation status to organisms, particularly animals, which states that "a species or population is qualified as "Critically endangered" if any two of these criteria apply: (1) total actual population <250; (2) population fragmented with ≤ 2 subpopulations of N<125 individuals; (3) census data show >20% annual decline in the past 2 years, or 50% decline in the last generation; and (4) population subjected to catastrophic crashes. Even though this study cannot provide data for population trend, the population status of Sokoke pipit in the Zaraninge forest qualifies for criteria 1 and 2 and possibly 4 if the current forest destruction in Zaraninge continues. Thus, for this reason, we are convinced that in Tanzania, this bird species has moved from its currently stated status of endangered to “critically endangered”. However, to tell this with certainty, more studies especially long term monitoring of its population trend are needed.

We recognise primary efforts that has been taken to protect the Zaraninge forest and the biodiversity therein by including a part of it in the recently established Saadani National Park, hence attaining a full legal protection, however there are still big challenges as the annex forest part in major part is still under the management of the local community. Considering the social economic status of communities surrounding this forest, and their need and dependence on the forest for energy plus expansion of land for agriculture, tree cutting for poles and other building purposes, and the fact that it is such anthropogenic pressure that has led to local extinction of Sokoke pipit in the Vikindu forest and other forests (Bird Life, 2011), there is no doubt that, if we do not help people to find ways to make a living that do not deplete their precious natural resources in the first place (WWF- East Coastal Forest Update, 2010), these birds in Zaraninge will follow similar line of their cousins in Vikindu and Pugu forests.

CONCLUSION AND RECOMMENDATIONS

Protecting endangered animal species is the first step to solving some of the problems pertaining species extinction. Unless we do, human life will fail as well. Our study of Sokoke pipit in the Zaraninge forest along the Tanzanian coastal forests helped us determine species habitat preference, distribution and abundance. By saving the areas preferred by these birds we can benefit birds’ life in other areas all along the Zaraninge forest. To create a sustainable future, we must help people find ways to make a living that do not deplete their precious natural resources in the first place. Key recommendations to enable this are: (i) Training of local communities regarding conservation, and supporting them with the tools and skills to practice it; (2) Training people in Ecotourism and the creation of markets for local crafts; (3) increase law enforcement, particularly forest patrols that will help in decreasing all activities which are not permitted by the regulations of Forest Reserves in Tanzania; and (4) Monitoring on the status of biodiversity and threats

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NOTES ON THE DISTRIBUTION AND GENETIC DIVERSITY OF ABBOT'S DUIKER CEPHALOPHUS SPADIX IN THE UDZUNGWA MOUNTAINS, TANZANIA.

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ABSTRACT

Abbott's duiker (Cephalophus spadix) is a forest antelope endemic to a very few highland forests in Tanzania. Apparently extinct over much of its historical range, the species is listed as Endangered by the IUCN based on its rarity and its likely current distribution in only four isolated upland areas: Kilimanjaro, Southern Highlands, West Usambara and Udzungwa Mountains. In contrast to the situation in the rest of its range Abbott's duiker is relatively well documented and locally abundant in parts of the Udzungwa Mountains, which may therefore be the only stronghold for the species. We review the distribution of Abbott's duiker within the Udzungwa Mountains and present new information based on the non-invasive genetic identification of dung piles collected from the majority of forest blocks between 2006 and 2010 (73 confirmed dung samples). Our results include new records from outlying forest blocks where the presence of Abbott's duiker was previously unknown. Moreover we present the first population-level analysis of genetic structure and diversity in this endangered species based on nuclear microsatellites and mitochondrial sequence data. While these genetic results should be considered preliminary due to small sample sizes they indicate some differentiation from other Abbott's duiker populations as well as low genetic diversity relative to sympatric antelope species. Finally we discuss threats to Abbott's duiker, and other antelope populations, in the context of our results and identify broad trends within the differently managed Udzungwa Mountain forests that suggest potentially successful conservation strategies for this neglected species.

INTRODUCTION

The highland forests of Tanzania are amongst the most important areas in the world for biodiversity conservation due to the exceptional density of threatened and endemic species found there (Burgess et al. 2007). These forests are also of great value to the people of Tanzania through their provision of ecosystem services such as watershed protection and carbon sequestration (Burgess et al. 2009). The endemic species of Tanzania's highlands are valuable indicators of the health of these important ecosystems.

One of the most threatened highland endemic species of Tanzania is Abbott's duiker (Cephalophus spadix) a forest antelope found in only a few upland areas. This duiker species is notable for its head crest of pink or red hair and its large body size (Kingdon 1997). Despite these characteristics it is very rarely seen due to its secretive behaviour (often crepuscular or nocturnal), densely vegetated habitats and naturally low population density. The species is threatened by habitat loss, due to agricultural encroachment and selective logging, and hunting, particularly with snares, ongoing in many areas (Moyer et al. 2008).

Not much is known about the historical distribution of Abbott's duiker but the species has long gone unrecorded in many sites where it was formerly known including the Uluguru and East Usambara Mountains, the Gregory Rift forests, and the Poroto Mountains and Njombe escarpment in southern Tanzania (Moyer 2003). This apparent decline resulted in the species' IUCN Red List status being changed from Vulnerable to Endangered in 2008 (Moyer et al. 2008). This assessment considered Abbott's duiker to survive in just four isolated mountain ranges: Kilimanjaro, Udzungwa, West Usambara and Southern Highlands (Mount Rungwe and Livingstone forest). A small isolated population had also been discovered in the southern Rubeho Mountains in 2006. No information on abundance was available from Kilimanjaro or West Usambara, and the species was considered very rare in the Southern Highlands (Machaga & Davenport 2009), leaving the Udzungwa Mountains as the only known stronghold for the species.

The Udzungwa Mountains in south-central Tanzania are the southernmost and largest block of the Eastern Arc Mountains (Fig. 1). Many of the area's forests are protected by the Udzungwa Mountains National Park and the more recently gazetted Kilombero Nature Reserve however other forests are less well protected and threatened by illegal activities (e.g. Rovero et al. 2010). This variation in protected status was reflected in the Red List's assessment of Abbott's duiker within the Udzungwas with the species listed as "locally common" in Mwanihana, Luhomero and Ukami (the latter only 7 km2) and "rare" or "scarce" in Matundu, Nyumbanitu and Uzungwa Scarp (Moyer et al. 2008). The status of Abbott's duiker in several other forests was unknown.

Knowledge of the status of Abbott's duiker in the Udzungwas has increased greatly since the last Red List assessment due to extensive survey work and the use of remotely triggered camera-traps (Rovero et al. 2005) and non-invasive genetics (Bowkett et al. 2009a; Bowkett et al. 2009b). These techniques not only provide more reliable survey methods than traditionally available but also a wealth of further information on abundance (Rovero & Marshall 2009), habitat-use (Bowkett et al. 2008), and, in the case of genetic analysis, population structure and genetic health (Beja-Pereira et al. 2009). Here we present results from recent surveys for Abbott's duiker, including all major forest blocks in the Udzungwa Mountains, and an exploratory analysis of genetic information recovered from dung samples collected during this work.

MATERIALS AND METHODS

We surveyed 24 sites within 10 forests throughout the Udzungwas between 2006 and 2010 (Fig. 1; Table 1). Within each forest we walked reconnaissance transects in a triangular configuration (typically 3 km per day) using hip-chains to record distance. Suspected Abbott's duiker dung piles, encountered along transects or elsewhere, were recorded and collected for genetic analysis (unless desiccated). We also employed camera-traps in many forests both specifically to detect Abbott's duiker and as part of other research programmes (e.g. Bowkett et al. 2008; Rovero & Marshall 2009).

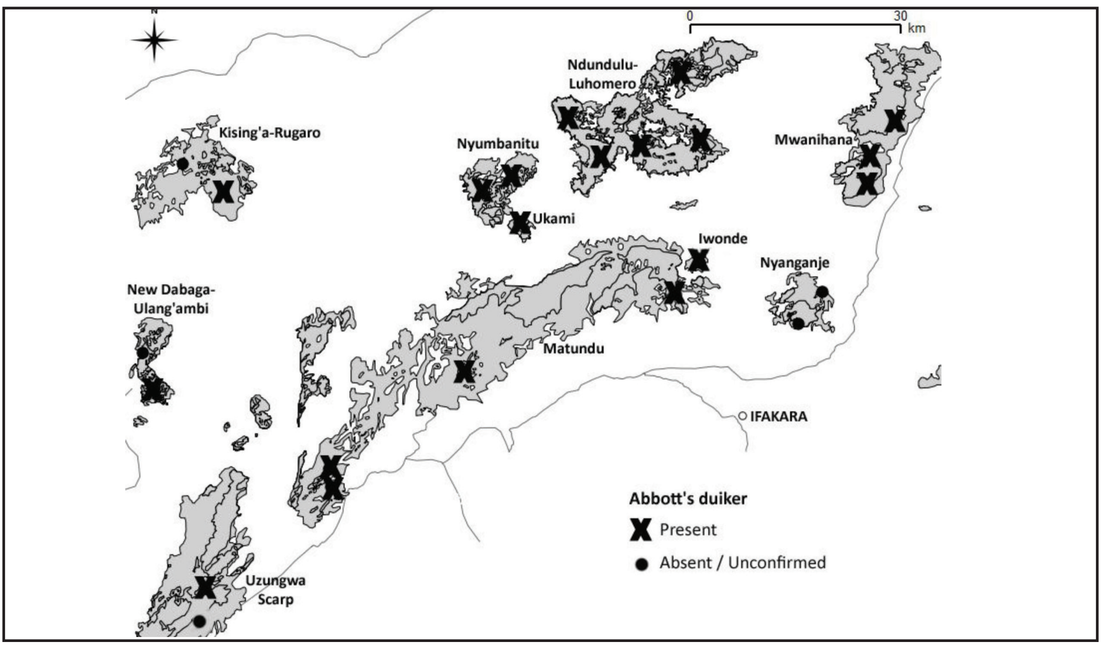

Fig. 1 Map of the Udzungwa Mountains, Tanzania, showing survey sites and recorded presence of Abbott's duiker (see Table 1 for more details). Outlined shapes represent closed- and open-canopy forest as identified from satellite imagery (Marshall et al. 2010)

Dung pellets were stored in RNAlater (Ambion Ltd) in the field and then kept refrigerated or frozen. DNA was extracted using the QIAamp DNA Stool Mini Kit (QIAGEN). To verify species identity and sample mitochondrial DNA variation we targeted a c.600 bp fragment of the left-hand domain of the control region using a combination of various primers (see Ntie et al. 2010a). Negative PCR controls were used throughout and PCR conditions followed Ntie et al. (2010a). To sample nuclear DNA variation we used seven microsatellite markers in two pre-PCR multiplexes: MPLX1 = INRA40 (Beja-Pereira et al. 2004), BM1225, BM2113 and BRRIBO (Bishop et al. 1994), and MPLX2 = BM143 (Bishop et al. 1994), INRA005 (Vaiman et al. 1994) and SR12 (Ntie et al. 2010b; modified from Kogi et al. 1995). We used the QIAGEN PCR Multiplex Kit (QIAGEN) following the manufacturer's instructions for degraded DNA including the addition of Q-solution and an extended annealing time of 3 minutes per cycle (35 – 40 cycles). PCR products were processed on a Beckman Coulter capillary sequencer and scored using CEQ 8800 software (Beckman Coulter, Fullerton, CA, USA). These markers have also been optimized for multiplex PCR and cross-species amplification in central African duiker species (Ntie et al. 2010b).

Sequence data were aligned using MUSCLE (Edgar 2004) and checked in SEAVIEW (Galtier et al. 1996). Species identity was established by visual inspection of aligned sequences and confirmed using the BLAST programme (NCBI, Bethesda, MD, USA). For the preliminary analysis presented here a neighbour-joining (NJ) tree was constructed in PAUP* (Swofford 2001) based on Kimura 2-parameter corrected distances (Kimura 1980). The tree was rooted with two sequences for bay duiker C. dorsalis as a monophyletic outgroup sister to Abbott's duiker reflecting published duiker phylogenies (Jansen van Vuuren & Robinson 2001; Ntie et al. 2010a). The neighbour-joining analysis included all haplotypes recovered from dung and tissue samples in the Udzungwas (Table 1) and the Southern Highlands (S. Machaga & T. Davenport, Wildlife Conservation Society) plus all published control region sequences for Abbott's duiker and its sister species, the yellow-backed duiker C. sylvicultor.

For microsatellite loci we attempted to score each allele at least four times from separate PCRs to avoid the problems associated with reproducing consistent profiles from faecal DNA (Taberlet et al. 1999). We constructed a neighbour-joining tree based on Nei et al. (1983)'s genetic distance in POPULATIONS (Langella 1999) including all available genotypes from the Udzungwas and Southern Highlands and one from West Usambara (northern Tanzania). Standard genetic diversity values for both data sets, and deviations from Hardy–Weinberg and linkage equilibria in the microsatellite data, were tested for using Arlequin 3.5.1.2 (Excoffier et al. 2005). Samples from outside the Udzungwas were excluded when calculating diversity values.

RESULTS

We confirmed a total of 73 antelope dung samples from eight different forests as Abbott's duiker (Table 1). Many samples identified as Abbott's duiker in the field were in fact Harvey's duiker C. harveyi or bushbuck (Tragelaphus scriptus) and so were excluded from this study. In addition, we obtained camera-trap records from six forests including Ukami for which we were unable to collect dung samples.

While we included 14 control region haplotypes in our phylogenetic analysis, only six were recovered from the Udzungwas and the vast majority of samples shared one particular haplotype (Table 2). Almost all Udzungwa haplotypes were unique to that region (Table 2). There was strong bootstrap support for the monophyly of Abbott's duiker with respect to its sister species as expected (Fig 2). The microsatellite tree showed differentiation between regions with a distinct Southern Highlands clade (Fig 3).

Nineteen microsatellite genotypes from Udzungwa samples were included in our analysis of genetic diversity for this population (Table 3). Two of these samples did not meet the requirement of four repeats (but only at one locus) and a further sample had missing values at one locus. Identical genotypes were excluded to avoid including multiple samples from the same individual (one case). Two pairs of loci had significant Linkage Disequilibrium values, BM2113 with INRA40 (P = 0.043) and also with INRA005 (P = 0.001). BM1225 was monomorphic within the Udzungwas, although not in other regions. Overall heterozygosity values were relatively low (Table 3).

Table 1 Forest characteristics and Abbott's duiker survey results for ten forest blocks in the Udzungwa Mountains, Tanzania. CT = camera-trap; S = sightings.

Forest	Size (km^2)	Elevation (m)	Walked transects (km)	Faecal DNA records	Other records
Matundu	526	279-1,046	40	6	CT,
Uzungwa Scarp	314	290–2,144	25	1	S*
Luhombero- Ndundulu	231	1105–2,520	76	17	CT, S
Mwanihana	151	351–2,263	68	33	CT, S
Kising'a-Rugaro	116	1,627–2,322	30	1	-
Nyumbanitu	57	1,074–2,322	27	2	CT
Nyanganje	42	350–1,038	23	0	-
New Dabaga - Ulang'ambi	40	1,764–2,081	21	4	-
Ukami	7	902–1,651	10	NA**	CT
Iwonde	5	980-1,472	9	9	CT

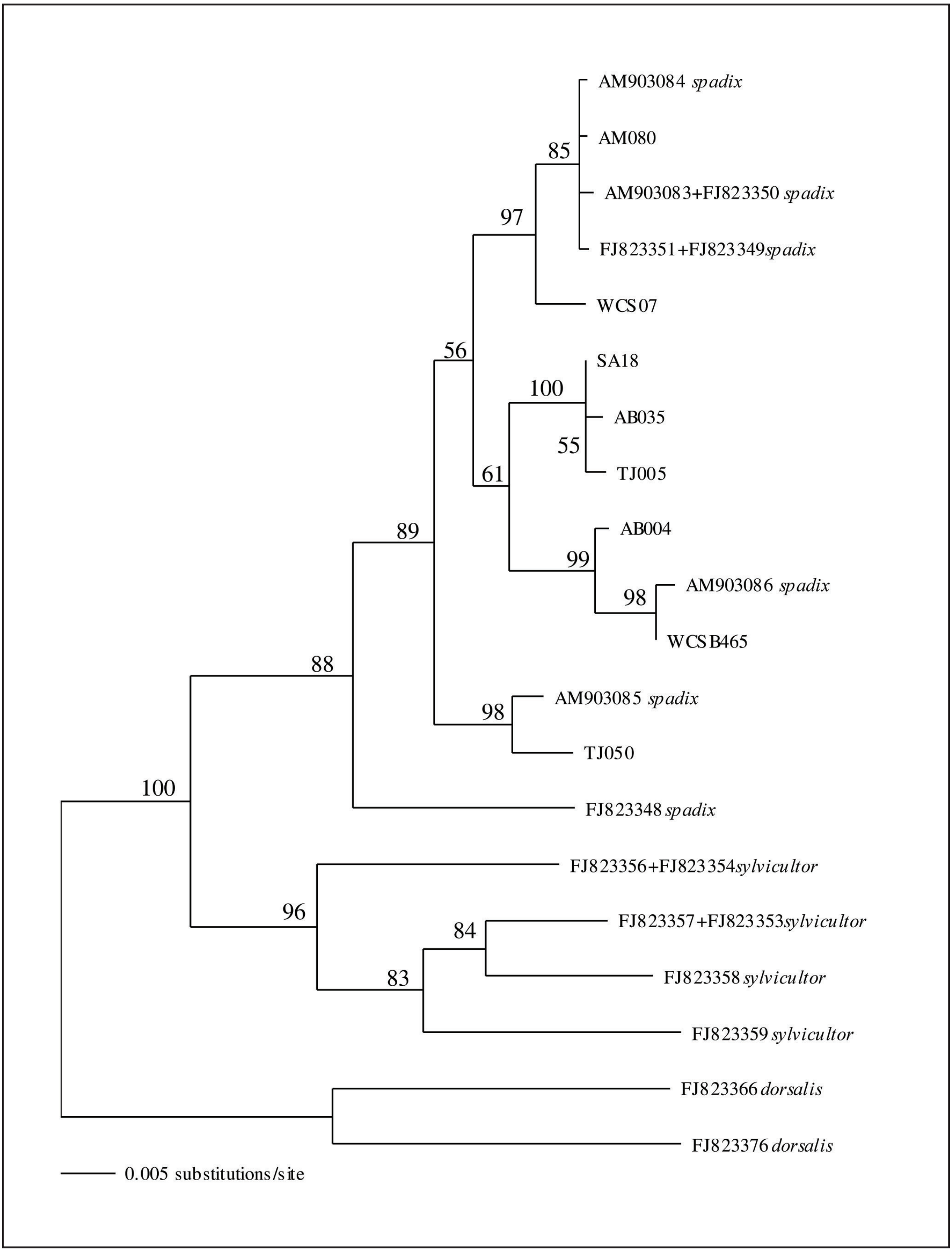

Fig. 2 Control region neighbour-joining bootstrap consensus phylogeny for C. spadix from the Udzungwa Mountains (c.600 bp). Bootstrap values are percentages of 1000 iterations (values below 50% not shown, results shown as polytomy).

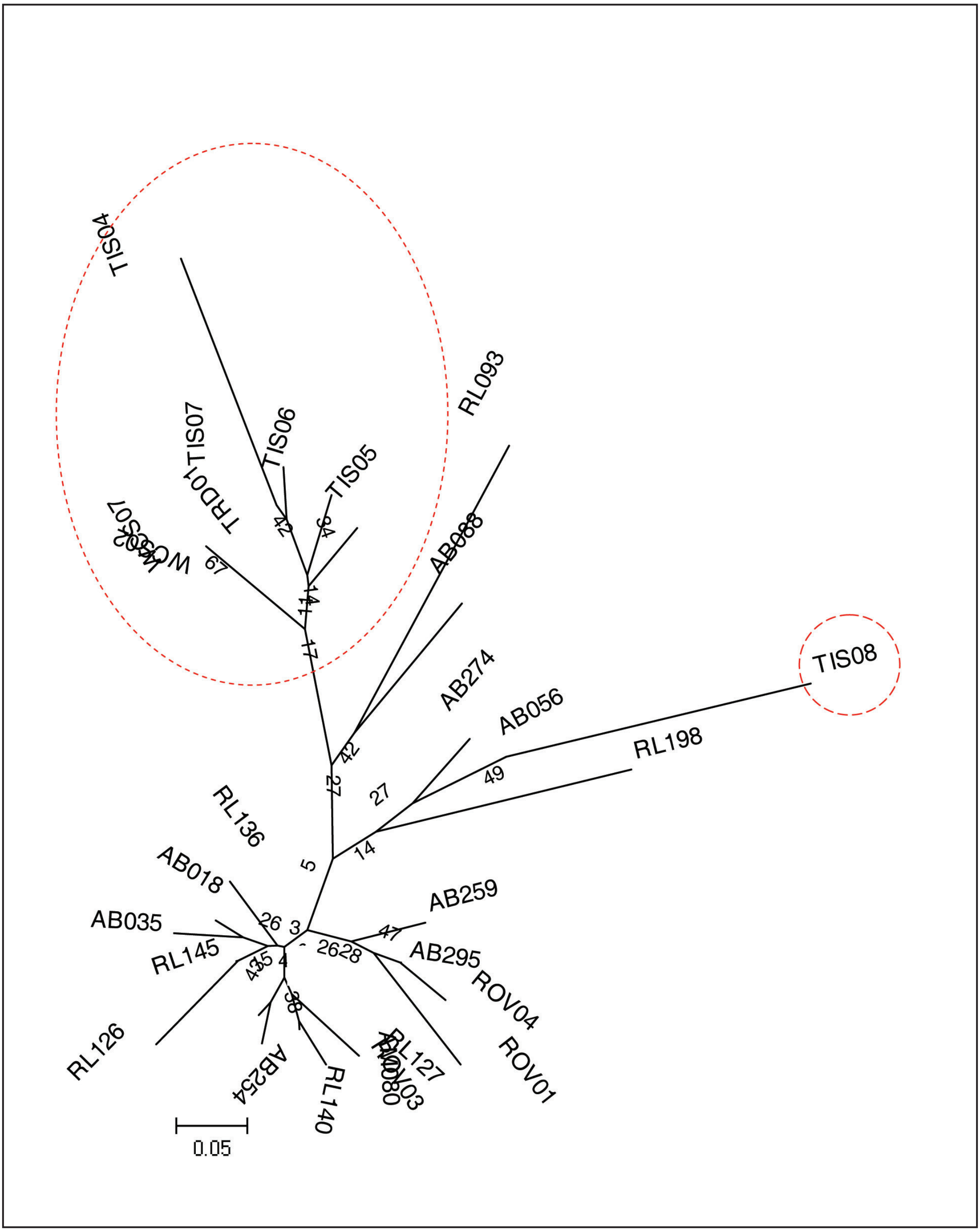

Fig 3. Neighbour-joining dendrogram showing relationships between Abbott's duiker genotypes using DA distances (Nei et al. 1983). Bootstrap values are the result of 1000 pseudo-replicates (some values <5% not shown). Genotypes from the Southern Highlands (top left of figure) and West Usambara (TIS08 on right) are encircled.

Table 2 Frequency of Abbott's duiker mitochondrial control region haplotypes recovered from the Udzungwa Mountains with available data from other regions. MA = Matundu, LU = Luhomero-Ndundulu, UZ = Uzungwa Scarp, MW = Mwanihana, KR = Kising'a-Rugaro, NY = Nyumbanitu, ND = New Dabaga-Ulang'ambi, I = Iwonde.

Haplotype	Udzungwa	Southern Highlands	West Usambara	Udzungwa forests
AM903084	0	0	2*	
SA18	57	0	0	MA, LU, MW, NY, ND, I
AB004	7	0	0	MA, UZ, MW, ND
AB035	3	0	0	MA, MW
AM903086	0	6	0	
WCS07	0	2	0	
WCSB465	0	2	0	
AM903085	0	2	0	
TJ005	1	0	0	KR
TJ050	4	0	0	LU, MW, I
AM080	1	0	0	LU
AM903083	0	0	2	
FJ823349	0	0	2	
FJ823348	0	0	1	

Table 3 Number of alleles (Na), observed (HO) and expected (HE) heterozygosities, and Hardy-Weinberg probability values (HW) for microsatellite loci and genetic diversity values for the mitochondrial control region in Abbott's duiker within the Udzungwa Mountains

Locus	N_a	H_o	H_e	HW (P-value)
BM2113	5	0.47	0.72	< 0.05
INRA40	4	0.37	0.47	NS
BRRIBO	5	0.68	0.67	NS
BM143	3	0.32	0.28	NS
INRA005	2	0.06	0.06	NS
SR12	3	0.11	0.10	NS
Mean	3.67	0.33	0.38	
Control Region	Number of haplotypes	Polymorphic sites	Gene diversity	Nucleotide diversity
	6	27	0.381	0.006

DISCUSSION

As an endangered species found only in Tanzania our results for Abbott's duiker in the Udzungwa Mountains have global conservation significance. These surveys have confirmed Abbott's duiker from nine forests in the Udzungwa Mountains including three areas without molecular or camera-trap records prior to this study (Jones & Bowkett In press). While the species was already known from New Dabaga-Ulang'ambi (Nielsen 2006) we provide the first records from Iwonde, a small forest patch within the National Park, and Kinsing'a-Rugaro, a much larger outlying forest that has been heavily hunted and logged (Marshall et al. 2010; Jones unpubl. data).

Almost all the recovered control region haplotypes were unique to individual regions (Table 2) but several were too similar to be resolved by the neighbour-joining analysis and many clades with strong bootstrap support contained sequences from more than one region (Fig 2). This preliminary analysis therefore provides little evidence for geographic structuring of mitochondrial lineages. One possible explanation for this is incomplete lineage sorting whereby haplotypes may have undergone small sequence changes but there has not been sufficient time for groups of related haplotypes to become fixed in particular areas (Maddison & Knowles 2006).

In contrast our microsatellite analysis appears to differentiate genotypes from the three sampled regions (Fig 3). This result may reflect the more rapid evolution of microsatellite markers compared to mitochondrial DNA but caution should be taken in interpreting this preliminary analysis given the restricted sample sizes and marker limitations (see Results). Furthermore bootstrap support was generally low for the main clades although this may reflect the limited information available for reconstructing evolutionary relationships from such a small number of loci.

Overall genetic diversity values were very low for Abbott's duiker compared to a similar analysis for Harvey's duiker in the Udzungwa Mountains (Bowkett et al. 2009b) or published values for other mammal species (see Appendix 1 of Gebremedhin et al. 2009). For Harvey's duiker thirty different control region haplotypes were recovered from 62 samples (Bowkett et al. 2009b) compared to just six for Abbott's duiker (73 samples). In addition, one of the microsatellite loci examined in this study appears to have undergone fixation within the Udzungwa Mountains but was polymorphic in the single Usambara sample. This lack of diversity may be the result of habitat fragmentation and the resulting isolation of small subpopulations.

While historical reduction in the size of forest fragments has likely affected Abbott's duiker in the Udzungwas the most serious current threat is almost certainly illegal hunting. Hunting occurs throughout the Udzungwas, including within the National Park, but is far more prevalent in the outlying forest reserves including Kisin'ga-Rugaro and Uzungwa-Scarp where our surveys suggest Abbott's duiker is much less abundant (Table 1). The threat to the large mammal communities of Uzungwa Scarp is particularly severe as outlined in a recent report documenting population declines in antelope and primates (Rovero et al. 2010).

However in those forests where conservation action has been taken there is some evidence that Abbott's duiker populations may be able to recover. Martin Nielsen reports, in Rovero et al. (2010) that hunted species have increased in abundance in New Dabaga-Ulang'ambi following the successful introduction of domestic livestock schemes to local villages. Anecdotally there are also reports that Abbott's duiker has benefitted from anti-poaching patrols by National Park staff although Nielsen (2011) found that duiker dung densities remained approximately stable in Nyambanitu and Ndundulu forests between 2001 and 2008. These situations are in stark contrast to the example of the unprotected Uzungwa Scarp cited above.

While our survey results provide renewed hope for the survival of Abbott's duiker it is clear that the species remains threatened and potentially vulnerable to the negative impacts of small population size. We strongly recommend further survey work and non-invasive genetic sampling of Abbott's duiker in the Udzungwas and throughout the species' historical range. Prevention of further habitat loss and poaching is essential for the survival of the small isolated populations reported in this study and for the long-term viability of the species as a whole.

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UPDATES OF BIRDS SPECIES DIVERSITY OF NJIRO FOREST AND THE SURROUNDING AREA

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ABSTRACT

The study was conducted in Njiro Forest and its surrounding areas in Arusha Municipality from 25th February to 4thMarch 2010, it aimed at determining the current bird diversity and assess the species relative abundance. The encounter rate and mist net methods were used. A total of 53 species in 10 orders and 27 families were recorded. However, Common bulbul (Pycnonotus barbatus) ranked the highest with 581 counts. Several challenges were encoured; most of them were associated with human activities around the forest. The study thus, recommends that TAWIRI Management who is a custodian of the forest should come up with sustainable plan for the conservation of Njiro forest while insuring a sustainable resource use in the area.

Key words: *Njiro forest and bird diversity.*

INTRODUCTION

Birds can be found at different types of habitats, they can penetrate the remote deserts, oceans and mountains. In East Africa birds dominated virtually everywhere (Stevenson and Fanshawe, 2002). They are excellent natural indicator of the health of many ecosystems. Birds tend to be the first to disappear from an area where it normally signals the deteriorating health of an ecosystem. Bibby et al., (2000) has indicated that, “Birds can be useful indicators of the state of the environment and are also key species for education and public awareness”. A good example can be shown by the Grey Crowned Crane (Balearica regulorum) whose presence is a good indicator for undisturbed wetland. The disappearance of these birds within a particular wetland ecosystem indicates the disturbance within it. Birds can be found in one locality and not in another due to some pulling factors offered at a given area. They live where they can find most of their requirements like food (seeds, fruits, insects etc) and shelter (Mwakami, 2001). Availability of food and nesting strata and substrata seem to be important parameters in avian habitat selection. For example, greater food availability associated with human presence appears to benefit a number of avian species (Colburn, 1988).The avifauna of Tanzania include a total of 1108 species, of these, 23 species are endemic, 4 species have been introduced by humans, 43 species are rare or accidental, 36 species are globally threatened (Baker, 2000).

Factors affecting bird diversity

Pollution: The increased use of agrochemicals has been linked to the reduction in species richness in agricultural landscapes (Belfrage et al, 2005). The industrial liquids directed to important bird areas poses great risks to birds around the area.

Loss of habitat: This is due to conversion of habitat important for birds into human use, (Agriculture, settlements etc) which leads to the loss of habitat suitable for bird life. The increase in human population and unsustainable farming methods will results into mass distinction of birds within the area (Belfrage et al, 2005).

Deforestation:The increase of human population which results to high more demand for poles, charcoal making, timber harvesting, and fire setting by hunters or honey gatherer (Msuha, 1997).

Bird trade:This can lead to direct loss of birds from the wild. The export of birds which do not adhere to standards of packaging can subject to the death of birds in transit (Msuha, 1997).

Lack of awareness on the value of birds to people: People do not see the value of bids around their areas as the results human activities which destroy important bird habitats are not controlled. Un-prescribed fire can results in the reduction in plants species richness as well as reduce number of bird species depends on grasslands communities (Zimmerman, 1992).

Objectives

The general objective of this study was to conduct a further diversity survey of birds at Njiro forest and surrounding areas so as to determine the current situation. Specifically, it focused on :

i. To establish birds checklist of Njiro forest and surrounding area.
ii. To assess the relative abundance of bird species in the study area.
iii. To determine the current major challenges for bird diversity at Njiro forest.

METHODS

Location of the study

Njiro Forest is owned by Tanzania Wildlife Research Institute (TAWIRI). The entire area occupies about 23 ha, of which 16 ha is a forest dominated by Acacia species. The forest is on the slope of Njiro Hill (4˚S, 36˚E) plot number 213 (Block A), 5km Southeast of Arusha Municipality (Fig. 1). It receives an average rainfall of 800mm annually and has an average temperature of 24˚C.The place has been set aside for the experimental honeybee colonies. The area has black cotton soil with high water holding capacity and high cation exchange capacity. There are about 29 plants species, 81 butterflies' species and 61 birds' species (Flora, 2002).

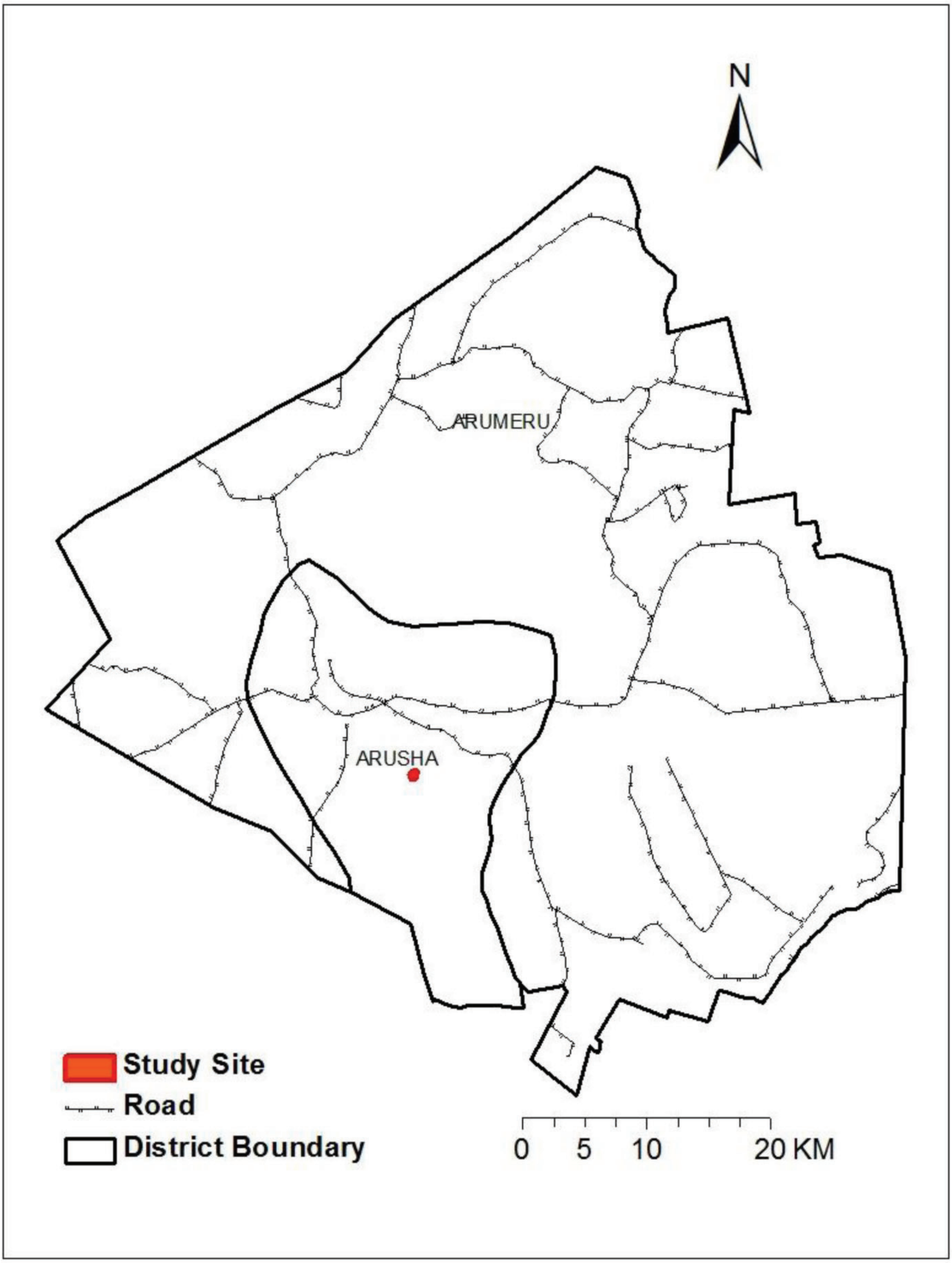

Figure 1: Map of Arusha Municipality showing the Study Area

Study design

The forest was stratified into two sites i.e. site A and B, site A was away from human settlement not in a disturbed side while site B was closer to the human settlement, encompassing a wetland covered with Typha plants. Data were collected for 6 hours a day from 6.30 a.m to 9.30 a.m and from 3.00 p.m to 6.00 p.m. when the activities of birds were prominent (Pomeroy, 1992; Volpato et al, 2009).

Data Collection

Relative abundance of bird species

Trails inside the forest and in the surrounding areas were walked and all bird species encounter within 20 m on each side of a trail were counted. The procedure was repeated for eight days consecutively. Additionally, all birds heard during counting sessions were also recorded. Species not identified in the field were either recorded using a tape recorder (calls/voice) or photographed for identification later on. The start and end time for each survey session were also recorded to establish duration of each counting bout, which allows an encounter rate to be calculated for each species.

Bird species list of Njiro forest and surrounding area.

In addition to trail survey, two sets of mist nets were set inside the forest to understand the undergrowth forest birds and therefore, compliment information from the first method. Mist nets is an effective means of recording quiet and skulking species of the forest understory, which may not be recorded using other techniques (Bibby et al., 1998). The nets were set for three days in selected areas. Four points were selected basing on high vegetation cover to hide the nets from being seen by birds from a distance. The distance from one point to another was one hundred meters. Captured birds were removed from the nets identified (Stevenson & Fanshawe., 2002), and then released.

Data analyses

Shannon-Wiener Index (H´) (Shannon & Weaver 1949) was used to calculate bird's species diversity. $H' = -\sum pi*Inpi$, H' being the index (Pomeroy, 1992). Relative abundance for each avian species was determined as a percentage of total number of all species at a given area whereas encounter rate of each species was computed by dividing the number of birds recorded for the species per survey time, giving a figure of birds per hour for each species (Bibby et al., 1998).

The encounter rate gives crude ordinal scales of abundance, frequence, uncommon and rare (Bibby et al., 1998). Therefore, five abundance categories (the number of individuals per 48 field hours) were used :< 0.02, 0.02-2.0, 2.1-4.0, 4.1-12.0 and > 30. For each category, the following abundance score was given: 1 (rare), 2 (uncommon), 3 (frequent), 4 (common), and 5 (abundant).

RESULTS

Species list

A total of 53 species in 10 orders and 27 families were recorded (Appendix I&Appendix II). Most of the species were found occurring in four orders namely, Passeriformes, Coliiformes, Columbiformes and Galliformes. Species like Common Bulbul and Speckled mousebird were found in large number compared to other species. A total of 9 species were captured by mist nets during the study (Figure 2) the most birds captured were Common Bulbul, this relate to their abundance followed by Bronze Mannikin and Brown-crowned tchagra was the least (Apendix IV).

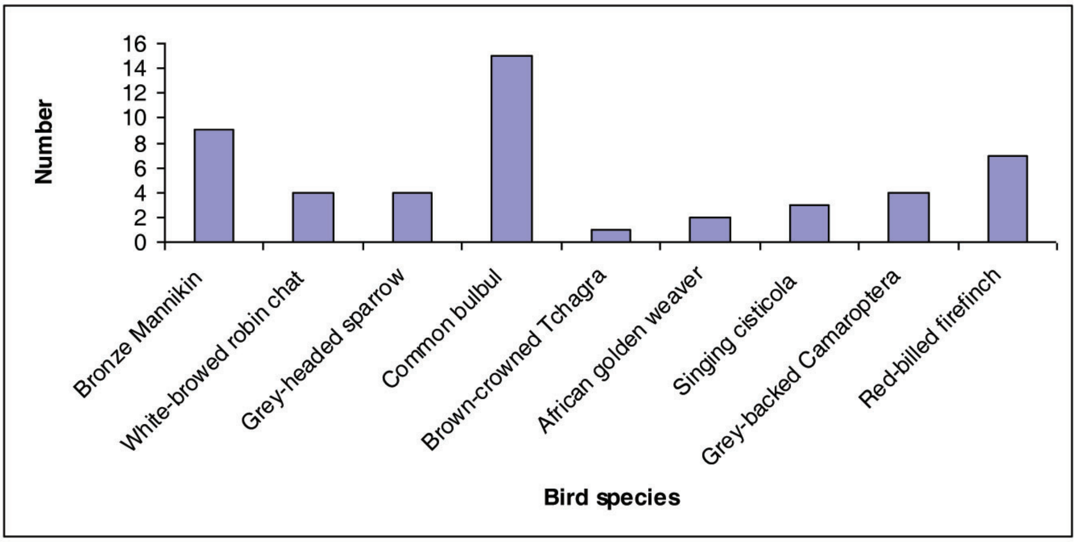

Figure 2: Species captured by mist nets

Species diversity

Birds diversity inside Njiro forest and surrounding area show that, Common bulbul is the most abundant species having a diversity index of H'= 3.164, with 581 counts. European Honey-Buzzard ranked the lowest with one individual being counted.

Relative Abundance

There was untested difference in relative abundance of birds between species, with Common bulbul forming the majority.

Common bird species according to numerical status includes Common Bulbul, Speckled mousebird, Red-billed Firefinch, Black and white Mannikin and Red-eyed dove while the rare species included European buzzard, Klaas's cuckoo, Lilac breasted roller, Magpie kingfisher and Pin-tailed whydah (Appendix V). Bibby et al., 1998, explained five criteria for determining the relative abundance in which applied to categorize the relative abundance portrayed in figure 3.

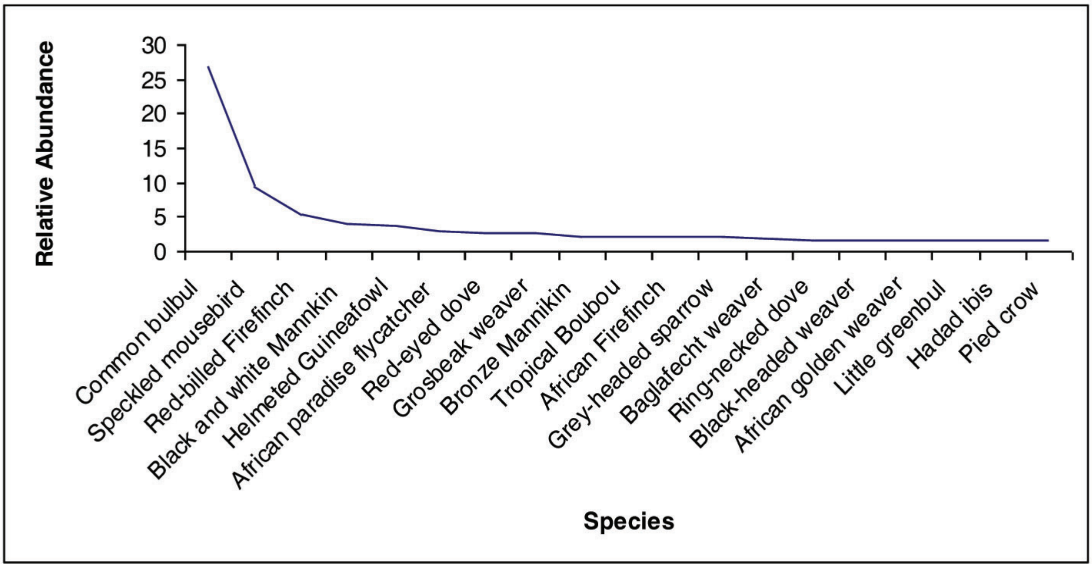

Figure 3: Relative Abundance against species

DISCUSSION

Species list

Forest birds were hard to see and their calls were difficult to identify but after acquainting with them it became easier. The study was conducted in the short dry season between short rains and long rains. Therefore, the area was a bit dry without enough food for birds, particularly fruits and insects. Flora, (2002) conducted bird survey at Njiro forest for five weeks, between August and September 2002. In that study, a total of 61 bird species were recorded in 32 families and most of them were in family Columbridae, Ploceidae, Turdidae and Nectariidae.

Findings from this study revealed few bird species at Njiro forest compared to what was recorded in 2002 by Flora. A total of 53 bird species in 10 orders and 27 families were recorded in this study (Appendix I). Most of the species occurred in four orders namely, Passeriformes, Coliiformes, Columbiformes and Galliformes. This difference has been associated with different season when the two study were conducted. The current study was carried out in dry season which is thought to have less food for birds in the forest as compared to the study of 2002 which was done in wet season.

Few migratory birds were seen in this study; such as European bee-eater (Merops apiaster) and European Honey-Buzzard (Pernis apivorus). These birds were flying over the forest and they were not observed in a large number. Normally the migratory birds come to our country in late November to April (Stevenson and Fanshawe, 2002).

Relative Abundance

Common bulbuls were found to have a higher relative abundance of 26.7% (Appendix V), suggesting that this species is highly attracted to forest habitat probably due to good availability of fruits and insects in forest. The distribution and abundance of many bird species are determined by the composition of the vegetation that forms a major element of their habitats. Gaston et al., (2000) and Karr & Roth (1971 cited in Aynalem & Bekele 2008) note that, availability of food may be among the major factors contributing to higher abundance of a species in the area. As vegetation changes along complex geographical and environmental gradients, a particular bird species may appear, increase or decrease in number, and disappear as the habitat changes (Lee & Rotenberry 2005 cited in Aynalem & Bekele 2008). In the previous study by Flora 2002, Red-throated Twinsport and Brown-crowned Tchagra were found to be rare because they were difficult to be detected. In this study the rare species were European-Honey Buzzard, Pin-tailed whydah, Malachite kingfisher, Lilac breasted roller and Malachite sunbird (Appendix V). Some of them were seen only once like European-Honey Buzzard (Pernis apivorus)

Abundance of birds differs between species

The abundance of birds within the forest differs between bird species and this is due to the availability of food resources. The diversity index for the previous study was H'= 4.5083 (Flora, 2002) while this study the diversity index is H'= 3.164 (Apendix III). The possible reason for difference in diversity in two survey one is due to the seasonality when study was conducted, also the expansion of the human settlement around the area have cleared some of the micro-habitats and cause habitat to be not conducive for some forested birds.

CONCLUSION AND RECOMMENDATION

The present study showed that birds are more diverse in the forest even though so many years have passed from the last study. This study can be used as the baseline information for monitoring any changes in species diversity inside Njiro forest due to the increase of the human pressure in terms of activities and settlements around the forest as well as the climate change. TAWIRI Management should put more efforts in conserving the forest by putting sign posts informing the people around the area not to dispose their litter inside the forest. More awareness raising to communities living around is needed on the importance of the forest and the effects of disposing their litters inside the forest. A collaboration between TAWIRI and Arusha Municipal Council is needed for the protection of the forest, e.g. putting skip bins in the resident houses and encourage them not to throw litters inside the forest.

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THE IMPACT OF MAESOPSIS EMINII INVASION ON LAND-SNAILS DIVERSITY AND DISTRIBUTION IN INDIGENOUS FORESTS IN THE EAST USAMBARA MOUNTAINS, TANZANIA

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ABSTRACT
This study was conducted in indigenous forest, Maesopsis eminii forests of Eastern Usambara mountains in Amani Nature Reserve. Relative diversity, richness and abundance of snails was compared in between both habitats. Sampling was done using standard timed direct search and litter sample methods. A total of 3,148 specimens were collected and of which 46 snail species were recorded. Mean number of species per plot ranged from 28 to 31.5 in primary forests, 17 to 19 in secondary forests and 13 to 14 in plantations. Snail abundance per plot range from 191 to 254 for primary forests, 105 to113 for secondary forests and 90 to 96 for plantations. Overall species richness, abundance and Shannon diversity index declined with the increase in Maesopsis abundance. Plantations presented the most varied relative species abundance, ranging from 0.18 to 35.66%. Thirteen species recorded were not found in both secondary forest and plantations. Snails fauna is one of the threatened elements of the of East Usambara and. the use of abundance and distribution data of snails in the assessment of biodiversity values in Tanzania is recommended.

Keyword: *East Usambara, snails , biodiversity conservation , Maesopsis eminii*

INTRODUCTION
The past two decades have seen an increase of studies of the relationship between the distribution and abundance of terrestrial molluscs and environmental factors are increasing (Barker and Mayhill, 1999; Millar and Waite, 2002);, but there are no published data on Tanzanian land snails. Despite the importance of such research for developing appropriate conservation strategies (Lange and Mwinzi, 2003), much of the literature on land molluscs focuses on taxonomy, with ecological studies being few and far between in the tropics (Tattersfieldet al., 2001). Land snails have so far played little role in conservation decisions especially in the tropics due to lack of knowledge (Tattersfield et al., 2001). Thus, in order to fully utilize land snails in conservation planning it requires to raise their profile to the public.

Land snails belong to the second largest phylum after arthropods in terms of numbers and of species (Lydeard et al. 2004). They form an important component of the forest ecosystem by recycling nutrients and are the prey base for a number of small mammals, birds, reptiles, amphibians and other invertebrates (Lange, 2003; Deepak et al. 2010) also serve as an indicator of ecological conditions, and are very sensitive to climatic and ecological change With their generally low dispersal powers, land snails are good indicators of areas of conservation importance and endemicity as well as representative of other little-known leaf-litter/soil taxa of extreme diversity that are not usually indicated by better-dispersing arthropods (Solem, 1994; Moritz et al. 2001). Therefore, this study sought to investigate diversity, abundance and distribution of the land snails in indigenous and Maesopsis eminii forests in the East Usambara Mountains.

The Usambara Mountains in the Eastern Arc Mountains are famous for high levels of flora and fauna endemism in their forests (Rogers & Homewood, 1982; Hamilton & Bensted-Smith, 1989; Newmark, 2002), and they are regarded as one of the most vulnerable biodiversity loss and a priority for conservation investments. Forests in the Usambara have been exploited by man for at least 2000 years, and therefore, this have resulted in a major decline in forest cover, and over 57 percent of the natural forest has been lost (Newmark, 2002). The remaining forests of the East Usambara are generally small in size and though most of them are protected they are still seriously threatened by deforestation, fragmentation, degradation and over-exploitation of species (Newmark, 2002).

The integrity of the natural forest of the Amani Nature Reserve has been affected by varying levels of anthropogenic disturbance for several centuries. Since the area's designation as a reserve in 1979, its biodiversity has continued to be threatened mainly by bush fire and the rapid spread of invasive alien plants, especially Maesopsis eminii Engl. (Rhamnaceae), (Doody et al., 2001). In East Usambara, Maesopsis is most abundant in submontane forests and the biological richest zone lies at intermediate altitudes, between 800 and 1,200m (Stuart, 1983 and Iversen, 1991). The central African pioneer tree species Maesopsis were mostly introduced through the establishment of the Amani Botanical Gardens in the early 1,900s and which has extensively invaded the primary submontane forests (Binggeli; 1,989; Binggeli & Hamilton, 1,993). The tree is colonizing the natural forests, especially following disturbance of the canopy and have already invaded much of the sub-montane forest. Currently there is strong evidence that Maesopsis is causing major changes to the sub-montane forest ecosystems on the East Usambara, by altering the biology and physical properties of near-surface soils (Binggeli & Hamilton, 1993) which is likely to cause serious effects on the biodiversity of invertebrates and it is therefore important to assess the effect of Maesopsis spread on the diversity and abundance of forest floor biodiversity. Specific objectives of this study were; (i) to investigate whether land snails faunal composition and structure is significantly different between indigenous forest and disturbed and plantation stands.(ii) to investigate whether plantation forests, forests invaded by Maesopsis support the endemic-rich faunas known to be associated with undisturbed forest stands.

MATERIALS AND METHODS

The study area

The study was done in Amani Nature Reserve (5°1'410"-5° 04'30" S and 38° 30'34"-38° 40'06" E), the largest forest sector (8,380 ha forest) in the East Usambara. Most of the previous studies on land-snails in East Usambara were undertaken in forests in this sector (Emberton et al., 1995, and Tattersfield surveys 1995-6). Given that altitudinal variation in fauna is very strong in some mountains ranges in Tanzania including Eastern Arc mountains (Tattersfield et al., 1998), and Maesopsis is most abundant in submontane forests,the study was the only undertaken in forests and plantation at an elevation of between 850–1000 m. The following forests were surveyed:

- 3 indigenous forests - Amani East, Amani- Sigi and Bomole,
- 2 secondary forests containing abundant Maesopsis - Kwamkoro and Amani West
- 2 Maesopsis plantations - Kwamkoro and Amani near Forest Station Rest House

Sampling Design

Sampling was done at end of the dry season in March and August 2004 within 3 replicate plots (40 x 40m) randomly selected at each of the selected areas. Snails were sampled using a combination of standardized timed direct search and litter sieving methods (Tattersfield, 1996). In each plot, live snails and dead shells were searched and collected by 1 hour by a team of two people. Potential snail microhabitats (tree trunk base, under dead fallen wood, under leaf surfaces, on the forest floor litter) were searched. At the end of each searched period, each individual collected 4 liters of forest floor litter from each plot. The litter was later thoroughly air-dried under hot sun and sieved.

Data analysis

Three methods of determining species richness and diversity, total number of species recorded (S), mean number of species per plot and Shannon Weaver index (H) were calculated using the full data set of 21 replicate plots. The total number of individual (both living and dead specimens) was used as a measure of relative abundance. Chi-square test was used to examine the associations of species with the status of the forest/plantation. Significance levels have been adjusted using Shedak's adjustment to allow for repeated tests. Analysis of variance (ANOVA) examined differences between habitats and applied to species number (S), the Shannon Index (H) and the total number of individuals (snail abundance).

RESULTS

Variation in species, richness, diversity and abundance

In total, 46 species of snails were, with the overall totals of 46 species from indigenous forest. 32 from secondary forests invaded by Maesopsis and 20 from Maesopsis plantations.

Table 1 shows that species number, Shannon index and snail abundance varied strongly amongst the three habitats plots, with the indigenous forest stands supporting the highest values. Mean species number and Shannon index values are significantly higher in indigenous forest than in secondary forest and plantations ((t –tests all $P< 0.005$). Snails are more abundant in the indigenous forest plots compared with the secondary forest and plantations. In The Maesopsis plantations plots are significantly less (S) and diverse (H), and snails less abundant than in any of the two forest types plots.

Table 1. Species richness and abundance statistics for land –snail faunas in indigenous, secondary forests with Maesopsis and in Maesopsis plantations

	Indigenous forests			Secondary forests with Maesopsis		Maesopsis plantations	
	Bomole	Amani East	Amani Sigi	Kwamkoro	Amani West	Kwamkoro	Amani
Number of replicates	3	3	3	3	3	3	3
Total number of species (S)	42	44	42	31	32	18	20
Range of species per plot	26-37	24-33	21-29	16-21	11-23	12-14	11-17
Mean species per plot(α)	31.5	28.5	28	17	19	13	14
SE	5.57	4.72	4.16	2.51	4.58	1.15	3.055
Total number of specimens	574	762	644	314	338	289	269
Mean specimens per plot	191	254	214.77	104.67	112.67	96.33	89.67
SE	88.94	31.2	49.94	6.50	11.93	3.78	3.51
Overall Shannon index (H)	3.25	3.30	3.17	2.83	2.78	2.17	2.27
Range Shannon index	3.09-3.21	3.14-3.24	3.03-3.20	2.69-2.80	2.64-2.74	2.03-2.13	2.13-2.23
Shannon evenness index	0.87	0.87	0.95	0.83	0.80	0.75	0.76

Variation in the faunal composition and structure

There are major differences in the composition of the faunas and the relative abundance of species in the different three habitats. Thirteen species were only found in indigenous forest plots though recorded in low frequency (Table 2). These are Cyathopoma azaniense, Gonaxis usambarensis, Gulella amaniensis, Gulella ambonien-sis, Gulella grossa, Gulella peakei continentalis, Gulella usagarica agg, Gulella vicina vicina, Guppya quadrisculpta, Kaliella barrakporensis, Micractaeon koptawelilensis, Ptychotrema usambarense and Trochozonites usambarensis, most of them are litter-dwelling snails. Only four species, Euonyma magilensis, Hypolysia usambarica, Pseudoglessula boivini and Thapsia sp A were common whereby they comprised over 46% of the entire sample size.

The Shannon evenness index (Table 1). Shows that the indigenous forest support the most uniform mollusc community. In contrast the plantations are dominated by a relative small number of species and have lower values of the evenness index. Thapsia sp A. were by far the most abundant species in the plantation forests, contributing 10.1% of the total sample, whereas Euonyma magilensis was the most abundant species in the indigenous forest, where it represented 16% percent to the total fauna (Table 3).

DISCUSSION

The 46 species recorded in this study represent about 10% of the published species of East Africa (Tattersfield et al., 1998; Verdcourt 2006). and further the information that, Usambara support some of the highest levels of mollusc diversity in East Africa (Emberton et al, 1997; Tattersfield et al, 1998).

The findings support the often-made assumption that indigenous forests maintain higher levels of diversity than disturbed forests and plantations. Both alpha(plot) diversity and abundance were substantially higher in indigenous forest plots than in other forest types plots (Table 1).Further more fauna structure in terms of relative abundance of species was modified in a similar way in all three types of forests with an increased dominance of a small number of common species and decrease in the relative abundance of the less common species. Variation in the frequency of several individual species also demonstrate the biodiversity benefits of indigenous forests over other forest types maintenance of snail biodiversity (Cameron, 1978; Tattersfield et al., 2001; Lange 2003).

In this study, the Maesopsis forests plots did not support any additional species that were not found in the indigenous forests plots . Therefore, it would appear that the fauna associated with Maesopsis represents an impoverished version of the indigenous fauna, rather than being distinctive in its own right. Mahunka (1989) reported a

lower arthropod species diversity and more uniform, and with less local variation, under Maesopsis stands compared with primary forest (Binggeli & Hamilton, 1993). However, the gross abundance of arthropods was found to be similar in primary forests and Maesopsis plantations (Mahunka, 1989) while the present study found that Maesopsis plantations supported a much lower snail abundance than the other forests types.
Euonyma magilensis, which was more abundant in the indigenous forest plots Maesopsis plots, although it was not possible to identify the source of the association, might be useful as an indicator of indigenous forest condition in the Usambara.

The presence or absence of snail species in a given area is influenced by the interaction of several environmental factors (Mason, 1970) including leaf moisture, calcium levels, canopy cover, the abundance of fallen wood, tree sizes and the degree of soil compaction (Tattersfield et al., 2001; Lange & Mwinzi 2003). Maesopsis has been reported to influence all these conditions. MacFadyen (1989) has reported that, Maesopsis colonization is associated with a loss of organic soil horizons and a shallower litter layer composed mostly of twigs and small branches. The soil lacks the 5-10cm deep, dark, crumbly organic rich topsoil present in the indigenous forest, has a tendency to become dry and a compacted with lower pH and further more the is greater run-off and soil erosion (Binggeli & Hamilton, 1993). The findings of this study that the changes caused to the environment by the existence of Maesopsis to have strong impoverishing effect on snails communities in the study area.

CONCLUSION AND RECOMMENDATION

Conclusion

The number of snails recorded in this study is a contribution to further evidence of the critical role of East Usambara forest to conservation of snails fauna as well as other taxa occurring there. This study demonstrates a clear d decline in mollusc diversity and abundance where indigenous forests have been replaced by Maesopsis and is a further evidence, Maesopsis invasion have an impact fauna East Usambara. Maesopsis forests are poor versions of indegenous forests. Land snails and many other forest floor invertebrates fauna are likely to be one of the most threatened elements of the of East Usambara and East African fauna as a whole, because the majority are forests dwellers and are sensitive to habitat disturbance and changes in forest microclimate (Verdcourt, 1972; Emberton, 1995, Tattersfield et al., 2001).

Recommendation

There is a need for conservation of indigenous forest and the inclusion of snails in conservation efforts in Usambara and Tanzania as a whole. Land snails are exceptionally simple and rapid to sample (local foresters can easily carry out sampling programme), they are relatively robust to store and they can be surveyed throughout the year (unlike many arthropods which need to be sampled at a certain times), in the assessment of biodiversity values in Tanzania, and more widely in East Africa.

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CAMERA TRAPS ENHANCING ECOLOGICAL STUDIES OF BLACK-AND-RUFOUS ELEPHANT SHREW (*Rhynchocyon petersi*) IN COASTAL FOREST, TANZANIA

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ABSTRACT
Knowledge on the ecology of most giant elephant shrews or sengis of the genus Rhynchocyon is limited and yet an understanding of the factors determining their distribution, activity and abundance is critical to the conservation of these threatened species. We conducted a range of studies on the ecology of one of the giant sengi, Black-and-rufous (Rhynchocynpetersi) in the coastal forests found within and around Saadani National Park, Tanzania. In this study we deployed camera trapping to investigate the distribution and activity patterns of Rhynchocyon petersi in Zaraninge forest. Nine hundred and forty photographs were obtained, with 134 being of Rhynchocyon petersi. Using generalized linear modelling we observed differences between camera traps placed on the edge (P=0.099) and the interior of the forest. Activities were significantly higher during the morning (P<0.001) than afternoon regardless of the placement of the camera traps. We further report on the other species of animals trapped by cameras during the study period.

INTRODUCTION
The Black-and-rufous sengi Rhynchocyon petersi belong to the order Macroscelidea commonly known as Sengis or Elephant shrews. The order which is known to be endemic only to Africa (Corbert and Hanks, 1968) comprise a single family Macroscelididaewith 17 extant species. The family has two subfamilies: the Macroscelidinae consisting of 3 genera, Macroscelides (one species), Petrodromus (one species) and Elephantulus (13 species). The second sub-family Rhynchocyoninae comprise of one genus Rhynchocyon which are commonly referred to as “giant” sengi or elephant shrews (FitzGibbon and Rathbun, 1994). The genus Rhynchocyon up to the end of 2007 had only three known species: the Golden-rumped elephant shrew Rhynchocyon chrysopygus, Chequered elephant shrew Rhynchocyon cirnei and the

Black-and- rufous elephant shrew Rhynchocyon petersi. The fourth species of the genus, the Gray faced elephant shrew Rhynchocyon udzungwensis was described by Rovero et al. (2008) in 2008 while studying duikers using camera traps in Udzungwa Natioanal Park, Tanzania. Recently, Andanje et al.(2010) had a suspect on one of the photo specimen from their camera traps and one voucher spcimen from a net trap in northern Kenya forest which may probaly be described as a fifth species of the genus Rhynchocyon.

All the four species in the genus Rhynchocyon known share similar life histories in that they arediurnal insectivores that live in lowland and mountain forests and dense woodland (Rathbun, 1984) in altitudes ranging from sea level to 2300 m (Coster and Ribble, 2005). While foraging they use their long proboscis to turn over leaf litter and dig up beetles, termites,centipedes and other arthropods. Once the arthropods are exposed the sengi's prehensile tongue extends out of mouth and scoop them up (Kingdon, 1997). They all make nests from leaf litter on forest ground floor which they use for shelter. For example, the dimension of the nest used by R. chrysopygus it is an average of one metre wide with a body-sized bowl of 20cm long, 15 cm wide and 10 cm deep (Rathbun, 1979). Nevertheless, of the giant elephantshrews, the most is known about R. chrysopygus and there are few records on R. petersi (Rathbun, 1979; FitzGibbon,1997; Coster and Ribble,2005). One of the challenges in studying the ecology of giant elephant shrews are the methods that are employed, which were designed to study other groups of animal such as elephantulus and rodents which involve trapping and baiting. These methods donot work for studies on the giant elephant shrews. Studies of giant sengis depend mostly on catching them using non-baited traps such as nets, Tomahawk, Havahart and modified wire cage traps (Rathbun, 1979; FitzGibbon, 1995; Rovero et al., 2008 and Sabuni et al., 2011).

In this study we deployed camera traps as one of the methods for colecting data on the ecology of R. petrsi in Zaraninge coastal forest.The main objective was to determine presence, distribution and activity patterns of R. petersi. The study reports also other small to medium size species of mammals found in Zaraninge forests. Having basic knowledge on the presence and distribution of a species is crucial for planning and evaluating the status and conservation strategies.

MATERIALS AND METHODS

Study site

The field work was carried out in the Zaraninge coastal forest, within the Saadani National Park of Tanzania (SANAPA). The Park was gazetted in 2005 and covers an area of of 1100 km2 and is one of 15 national parks in Tanzania. As the only park in Tanzania bordering the Indian ocean, it offers a unique combination of both marine and terrestrial wildlife combining savanna, grasslands, mangroves, coastal forests, beaches and sea wildlife.

Zaraninge coastal forest is located between 6°04'S - 6°13'S and 38°35'E-38°42'E, in the South-West region of SANAPA (Fig. 1) covering an area of approximately 21km2 (Kiwia, 2006). The forest covers the Kiono plateau rising about 160-300m above sea level between the lower Wami and Mligaji Rivers. The forest itself is the source to the short seasonal Mvave River, on which Saadani Village depends for water. Two rainy seasons influence the forest, from October to December and from March to June (average rainfall of 100 mm), as well as by tropical East African oceanic temperatures (Clarke and Dickson, 1995; Balduset al. 2001; Blöeschet al. 2002;Kiwia, 2006).

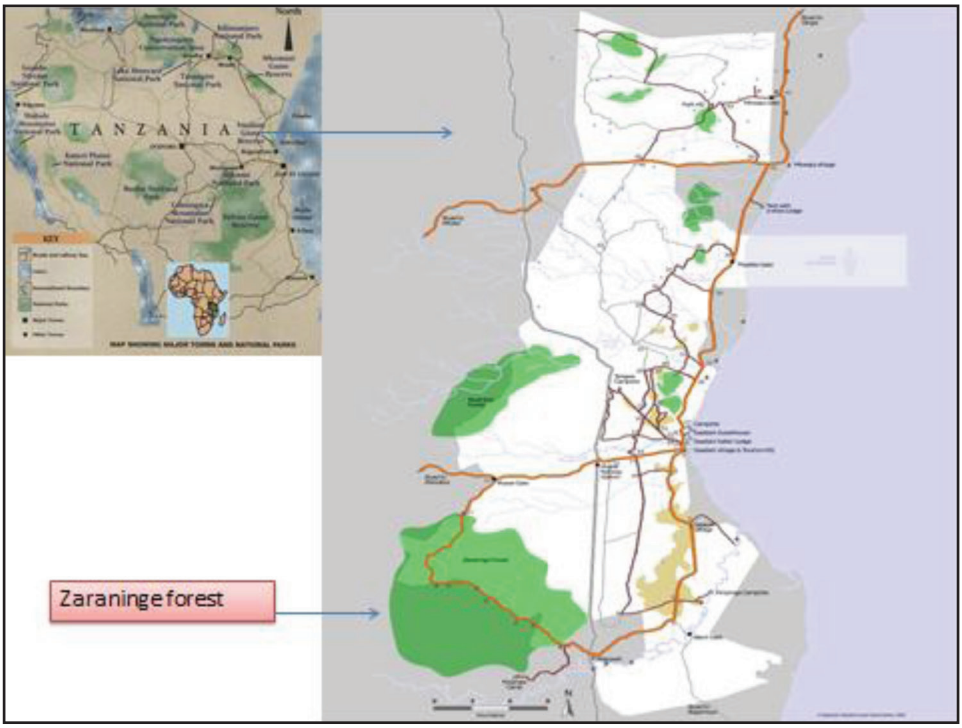

Figure 1: Location of Saadani National Park with Zaraninge forest on South West part of the park.

Camera trapping was carried out during wet season (March to May 2010) in Zaraninge forest. Nine cameras (ReconyxHC500) were spaced at 500 m using GPS coordinates from the edge to the interior of the forest. At each point of trapping a survey was made to find any possible path/runways which may be used by R. petersi. Camera were loaded with 12 alkaline AA Sanyo batteries and set up to an average height of 50 cm above the ground mounted to a tree using adjustable bungee provided, and programmed to take three photos per trigger with intervals of one second between pictures. The quiet period was set at no delay; sensitivity was also set at high

Cameras were programmed to operate 24h per day recording time and date with field camera number given to each camera at each point. The camera also recorded temperature and lunar phase. Camera traps were left at each site for 15 days before shifting to another site. Photo from camera traps were downloaded into a computer for identification using Kingdon (1997). All images identified were entered in a spread sheet form recording number of camera (n=27), date, time and observation (e.g. one animal per photo). The capture trap rates were calculated as independent photo of a species divide by the number of trap days (Yasuda, 2004; Bowkettet al., 2007). General linear model was used to analysis the activity patterns of R. petersi and to compare edge versus interior of the forest. Species richness was taken as the number of all species of animals that were photo captured.

RESULTS

Trapping efforts of 404 camera days were perfomed in Zaraninge forests generating 984independent photos for all species. Since the cameras were set to take three photos per triger per second it was obviously easy to observe if in that photo there was a single or a pair of individuals. However, that photo was treated as independet picture regardless of the number found within one phhoto as long as they were of the same species. A total of 18 mammal species of small to medium size were captured during the study period. Other non mammalian species included guinefowl, dove and monitor lizards. Four toed elephant shrew Petrodromus tetraductylus was captured most frequently followed by Rhynchocyon petersi (Table 1) (Fig.2). Three out of 27 camera traps set produced artifact results which generated hundreds of photos without any picture of an animal

Figure 2: A photo of Black-and- rufous elephant shrew Rhynchocyon petersi from camera trap (RECONYX HC500) captured in Zaraninge forest

Table 1: Results of camera trapping in Zaraninge forest, Saadani National Park Tanzania. Species are sorted according to the total number of independent photographs

Scientific name	Common name	% proportion of photo	Trap rate
Petrodromustetradctylus	Four toed sengi (n=540)	53.1	1.33
Rhynchocyonpetersi	Black-and rufous elephant shrew (n=134)	16.02	0.33
Cephalophusmonticola	Blue duiker	9.2	
Cephalophusharveyi	Harvey's duiker	8.1	
Cricetomysgambianus	Giant pouched rat	6.82	
Heliosciurusundulatus	Zanj sun squirrel	1.48	
Papio cynocephalus	Yellow baboon	0.84	
Atilaxpaludinosus	Marsh mongoose	0.74	
Gutterapucheran	Crested guineafowl	0.74	
*Genetta*sp	Genet	0.74	
Potamochoeruslarvatus	Bush pig	0.29	
Tragelaphusscriptus	Bushbuck	0.29	
Paraxeruspalliatus	Red-bellied coast squirrel	0.29	
Galagoides	Galago	0.29	
Beamyshindei	Lesser pouched rat	0.15	
Hystixcristata	Crested porcupine	0.15	
Mellivolacapensis	Honey badger	0.15	
Orycteropusafer	Aardvark	0.15	
Varanus	Monitor lizard	0.15	
Turturtympanistria	Tambaourine dove	0.15	

Activities of Rhynchocyon petersi

The activities of R. petersi wereobserved to be more pronounced during early to mid morning time (AM) for both sites at the edge and interior than the afternoon (PM) (P <0.001). Camera trapping with respect to placements on the edge and interior of the forest showed differences in favour of the edge (P = 099) . Graphicaly, if compared to the dominant captured species in photos, the four toed elephant shrew Petrodromus tetraductylus, a nocturnal species and Rhynchocyon petersia, a diurnal species, the former shows two peaks of activity during the sun set or just after the dark and just before sunraise (Fig. 3). The observations suggest the probability that R. Petersido use common paths/runaways with other animal such as P. tetraductylus and duikers. It is not clear whether they do make their own paths or not though our camera trapping aimed at path/runaways.On the other hand the study by Rathbun (1979) observed that R. chrysopygus does not make its own paths.

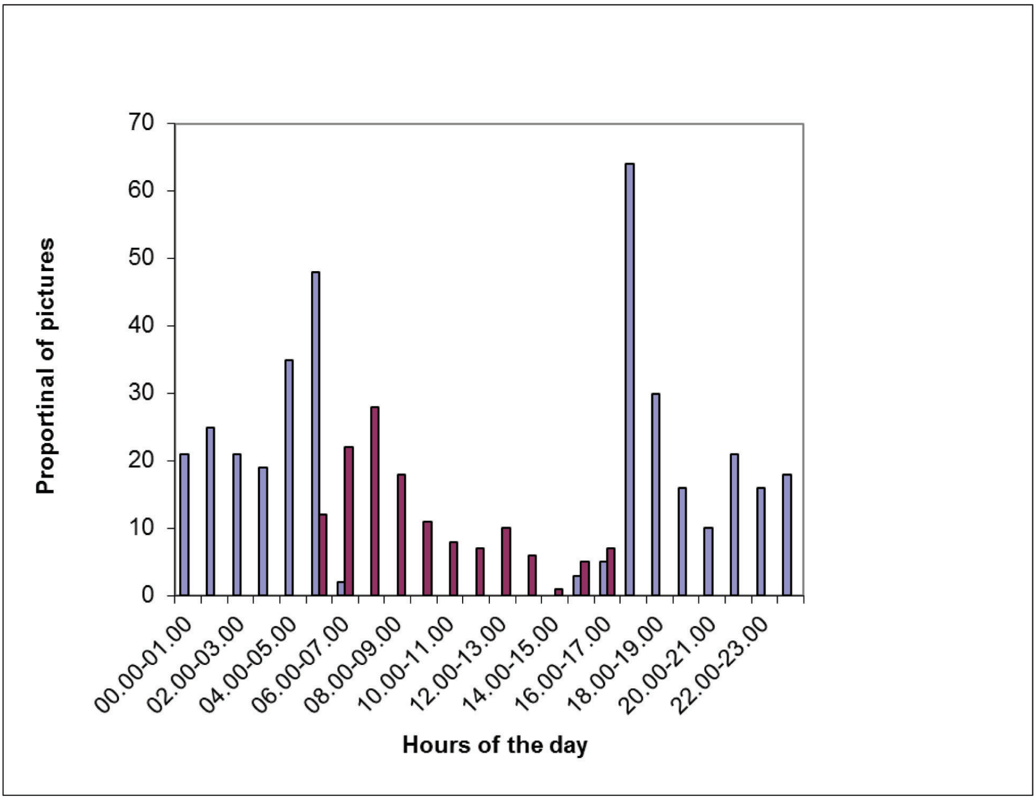

Figure 3: Activities of *Rhynchocyon petersi* (diurnal) and *Petrodromus tetraductylus* (nocturnal)

Rhynchocyon petersi ■ *Petrodromus tetraductylus* ■

DISCUSSION AND RECOMMENDATION

The results obtained from the camera trappings in this study confirm primarily that small to medium mammal species are present in Zaraninge forest. The relatively high propotion of elephant shrews based on indepedent photos (Table. 2) compared to other species of mammals suggestthat elephant shrews are dominant small mammals (excluding rodents) in Zaraninge forest. The most significant finding of this study was the activity patterns of Rhynchocyon petersi which was more pronounced during the mornings and slowing down during mid day. These results correspond to what was found in the study of Golden elephant shrew R. Chrysopygus by Rathbun (1979) and FitzGibbon (1995) on the same species which shows R. Chrysopygus to be highly active in the morning. Our results and those of Rathbun (1979) show that activities of the giant elephant shrewssuch as foragingand making nests are done mostly during morning. These activities are done during morning possibly due to the fact that leaf litters used to build nestsare still wet with dew and there is less sound produced during collection of leaves for building. Also the temperature in the forest is slightly lower during the morning compared to mid day.

Earlier studies by Hannah and Anderson (1994) and Kiwia (2006) have shown the presence of R. petersi in Zaraninge forest. This study also has confirmed the presence of R. petersi and its distribution pattern. The species is able to utilize different parts of the forests mainly the edge and the interior. The Zaraninge forest, is now protected within SANAPA but still borders some villages (Gongo and Mbwebwe). Farming activities by the communities surrounding the forest could have an adverse impact on R. petersi especially when they come to the edge of the forest.

The introduction of camera trapping in the ecological study of Rhynchocyon petersi has increased our understanding of this species in particularthe activity patterns and distribution of the species. Conservation involves not only understanding the inventory of species existing in an area, but also understanding thd ecology of individual species, which is crucial for planning on management strategies. From the results, it is obvious that a good conservation strategiesfor forests independent species is to consider setting a buffer zone as recommended by Hanna and Anderson (1994). These will save forests species which utilize both the interior and edge of the forest including our study species Rhynchocyon petersi.

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TRANSBOUNDARY MOVEMENTS AND HABITATS OF ELEPHANTS IN THE WEST KILIMANJARO REGION OF NORTHERN TANZANIA

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Key words: *Amboseli, elephants, Kilimanjaro, protected and unprotected lands, satellite tracking, transboundary movements*

ABSTRACT
Although elephants (Loxodonta africanus) of the Mt. Kilimanjaro region of northern Tanzania are considered distinct from those of the Amboseli Basin in southern Kenya, there is little information on transboundary movements and habitats used by elephants in these two areas. All eight satellite-collared elephants from West Kilimanjaro crossed the Tanzania-Kenya border, totaling 155 transboundary movements. Female elephants crossed the border 25% more frequently than bulls and were more frequent in the wet than the dry season for bull (83% higher) and female (75%) elephants. Collared elephants spent the vast majority of time in unprotected (= 92%) versus protected (= 8%) areas. Amboseli National Park (NP) was visited by all eight elephants and was the most utilized protected area (= 8%, range 2 - 24%). Within unprotected areas, four areas had high elephant use, including: the Oltupai Thicket, Sinya Mine, Kitirua Concession Area (CA), and the proposed Lemomo CA. The apparent shift in elephant movement patterns south of Amboseli NP may be related to changes in resource availability and human land use. Our conservation priorities for the elephants of West Kilimanjaro and Amboseli Basin focus on expanding anti-poaching efforts and securing conservation corridors for wildlife and cattle grazing.

INTRODUCTION
The elephants of Mt. Kilimanjaro were considered distinct from those of the Amboseli elephant population in southern Kenya (C. Moss, pers. comm., cited in Western & Lindsay, 1984) and rarely (Moss, 2001), if ever (Afolayan, 1975), dispersed into southern Kenya. Similarly, it was believed there was little movement of Amboseli elephants to the forests of Kilimanjaro (Western & Lindsay, 1984, Grimshaw & Foley, 1991). Western & Lindsay (1984) reported that Amboseli elephants ranged over a 3588-km2 area primarily to the north and west of Amboseli NP and had a maximum dispersal distance of no more than 50 km during the wet season. However, in their aerial surveys and radio-tracking study, Western & Lindsay [1984:233 (Fig. 1)] showed that

Amboseli elephants also ranged across the Kenya-Tanzania border to the south and west of Amboseli NP. Douglas-Hamilton et al., (2005) reported on the movements of two bull elephants tagged with GPS collars in Amboseli NP. Both bulls ranged widely outside of the park, spending 60% and 90% respectively, of their time outside of protected areas. One of these tagged elephants dispersed south, crossing the Kenya-Tanzania border to the Longido Game Controlled Area. Kikoti (2002) reported that 70 of the 100 elephants he photographed in West Kilimanjaro matched the photographs of recognizable Amboseli elephants in the Amboseli Elephant Research Project database. Further, he reported that elephants regularly used a 6-km-wide vegetation corridor to move between the forest border of Kilimanjaro NP and the Kenya-Tanzania border, and he suggested that some elephants might be moving far beyond West Kilimanjaro.

Despite these reports, the movement patterns of elephants in West Kilimanjaro are largely unknown. Further, elephants moving across the West Kilimanjaro landscape must cope with a complex mosaic of natural communities, agricultural fields, grazing lands, and human settlements; thus, there is a significant potential for human-elephant conflicts. With increasing human populations and loss of natural habitats in the region, this potential for conflict will increase. Thus, the goals of this project were to determine 1) extent of transboundary movements, 2) use of protected and unprotected areas, and 3) important areas used by elephants in the West Kilimanjaro region of northern Tanzania and Amboseli Basin of southern Kenya. Such information is critical for assessing the importance of immigration/emigration in the dynamics of this regional elephant population, establishing regional conservation corridors, and developing regional conservation plans for the elephants of West Kilimanjaro.

MATERIALS AND METHODS

Study area

West Kilimanjaro (West Kili) (3068 km2) is within the Longido, Arumeru and Siha districts of Arusha and Kilimanjaro regions of northern Tanzania (Fig. 1). The region is a complex mosaic of diverse natural communities, extensive grazing lands, and large agricultural fields at lower elevations on Mt. Kilimanjaro. There are traditional, agro-pastoral Maasai communities (n = 12) that graze cattle and other livestock and raise subsistence crops. In addition, there are five other moderately sized agricultural communities in the region. There are several protected areas in the study region, including Kilimanjaro NP (1665 km2) on the eastern boundary, Arusha NP (137 km2) to the south, and Amboseli NP (390 km2) in southern Kenya, 20 km north of the Tanzania-Kenya border. Additionally, there are two private conservation areas [West Kilimanjaro Ranch (303 km2) and Endarakwai Ranch (44 km2)], and the Longido Game Controlled Area (1700 km2) that provide habitats for wildlife.

Although variable with elevation (1230 to 1600 m), the predominate ecological zone is semi-arid savannah (Pratt et al., 1966) interspersed with woodlands, and there are extensive agricultural fields along the lower, western flank of Mt. Kilimanjaro, and lowland forests within the boundary of Kilimanjaro NP. Distribution of rainfall is unpredictable, especially at lower elevations, and highly variable from year to year. Rainfall amounts average 350 mm/yr in semi-arid lower elevations (KWS records, 1988) and 890 mm/yr in agricultural areas at lower elevations on Mt. Kilimanjaro (Rey & Das, 1996). Although northern Tanzania typically has two rainy seasons with the long rains from March to May and the short rains in November and December, we delineated November to May (7 months) as the wet season, corresponding to the period when vegetation was green and water is typically available in seasonal pans. We delineated June to October (5 months) as the dry season, corresponding to low precipitation and low water availability in seasonal pans.

Elephant collaring and monitoring

Eight elephants (3 bulls, 5 females) were fitted with satellite collars in West Kili in September 2005 (n = 6), January 2006 (n = 1) and November 2006 (n = 1)(Table 1). No more than one individual was collared within a herd. We also tried to choose herds that were widely separated from each other within an area to reduce the probability that herds were members of the same clan (Poole, 1996). For family groups, we targeted a middle-aged adult female in the herd for collaring. One subadult (18 - 20 yrs old) and two adult bulls (35 - 40 yrs old) were tagged in bull herds.

Six elephants darted from the ground and two darted from a helicopter were immobilized by a veterinarian using ethorphine hydrochloride (M99: C-vet UK) in darts fired from a modified .22-caliber rifle following the guidelines recommended by Thouless (1995). Once the elephant was immobilized and recumbent, it was fitted with a satellite telemetry unit; a blood sample taken; measures made of shoulder height, back length, tusk length, tusk basal circumference, and hind foot length and circumference; age estimated by size and head configuration; and health status evaluated. The effect of immobilizing drug was reversed using diprenorphine (M5050: C-vet UK).

We used GPS receiver collars on all elephants (African Wildlife Tracking, Pretoria, South Africa), and collared elephants were monitored for varying lengths of time, depending on collar performance (Table 1). The duty cycle of units was set to download three GPS fixes per day, one every eight hours (~0200, ~1000, ~1700 hrs). However, beginning November 2007 (wet season of 2008), the duty cycle of units T1 - 6 was reduced to two fixes per month to conserve battery life pending removal of collars. The geographic accuracy of locations was 15 m for six collars we field-tested prior to deployment.

Data analyses

We calculated numbers of elephant transboundary movements across the Tanzania-Kenya border by sex and season. We used movement points in conjunction with a 4-km-wide buffer (2 km on each side of the border) to distinguish between inadvertent border crossings of elephants that spent much time in habitats on and adjacent to the border versus elephants with directed transboundary movements between Kenya and Tanzania. Using ArcView, the location of each movement fix was located in the buffer or in Tanzania or Kenya using a spatial join of the buffer layer with the movement points. We considered a movement transboundary when two criteria were met: 1) an elephant crossed the border moving from one country to another, and 2) the movement extended at least > 2 km into the adjacent country. If an elephant crossed the border but did move further than 2 km away from the border and returned to the same country of entry, we did not consider this movement as transboundary.

Numbers of wet and dry season transboundary movements were weighted by number of months tracked in each season. Occurrences of elephants in protected versus unprotected areas were determined by plotting the number of fixes that occurred within each land use category during the entire tracking period for each elephant. We considered fixes in Amboseli, Arusha, and Kilimanjaro NPs as occurring in protected areas, while all other fixes were considered occurring in unprotected areas. Following the procedures reported by Douglas-Hamilton et al., (2005), we identified important elephant habitats by constructing a 250-m grid over the study area and calculating the frequency that elephant pathways crossed each grid square during the entire tracking period. Student t-tests were used to test for differences in transboundary crossings between sexes, wet and dry seasons, and time spent in protected and unprotected areas.

RESULTS

Transboundary movements

All eight elephants crossed the Tanzania-Kenya border, totaling 155 transboundary movements, but numbers of transboundary movements varied between bulls and females and between seasons (Table 1). Although female elephants crossed the border 25% more frequently than bulls, there was no difference in mean number of monthly transboundary movements between female (= 0.75, SD = 1.24, n = 26) and bull (= 0.61, SD = 0.80, n = 17) elephants (t = 0.44, df = 41, P = 0.66). There were no differences in numbers of transboundary movements between female and bull elephants in the dry (t = 0.144, df = 19, P = 0.886) or wet seasons (t = 0.680, df = 20, P = 0.504). However, two elephants (bull T9 and female T21) contributed disproportionately more transboundary movements, especially during the 2006 dry season for T9 and the 2007 dry season for T21. Excluding these two elephants, transboundary movements were much more frequent in the wet than the dry season for bulls (83% higher) and females

(75%); yet, these differences were not significant either for bull (t = 0.98, df = 10, P = 0.348) or female (t = 0.93, df = 11, P = 0.365) elephants.

Time in protected and unprotected areas

Based upon 14,287 fixes from eight collared elephants, the vast majority of time was spent in unprotected (= 92%) versus protected (= 8%) areas (t = 22.8, df = 8, P < 0.001) in the West Kili region (Table 2). Amboseli NP was visited by all eight elephants and was the most utilized protected area (= 8%, range 2 - 24%). There were very few occurrences of elephants in either Arusha or Kilimanjaro NPs. In unprotected areas, elephants occurred most frequently (68%) in the "Other" category, lands with no official designation for land conservation. Of the mapped unprotected areas, the Enduitmet WMA (227 km2) was visited by 7 of the 8 collared elephants, accounting for 20% of all locations in unprotected lands. Relatively little time (3%) was spent on the West Kilimanjaro Ranch (303 km2), and the narrow Kitendeni Corridor (35 km2) was only used by one (T21) of the collared elephants.

Important elephant habitats

The collared elephants of West Kilimanjaro ranged widely throughout the region; yet, four areas had unusually high elephant use (Fig. 1). Overall, the Oltupai Thicket is an important area for elephants, especially the southern portion southeast of the Tinga Tinga Village. Areas adjacent to the Oltupai Thicket also provide important elephant habitat, including the northeast corner of the West Kilimanjaro Ranch, western portion of the Livestock Research Center, and the southwest corner of Endarakwai Ranch. Much of this area is mixed agriculture and grazing areas with few scattered large trees and secondary growth with a narrow riparian-forested strip with fever trees (Acacia xanthophloea) along the intermittent Ngare Nairobi River. There is no livestock grazing on the Endarakwai Ranch. There are five artificial water sources, two in Tinga Tinga Village, and one each at Mbong'et, West Kili Ranch and Endarakwai Ranch. Seven of the GPS-collared elephants used the Oltupai area extensively during both the dry and wet seasons. Although there is much human activity in this area during the day, elephants hide in the thickets and narrow riparian forest during the day dispersing out to water sources, foraging areas and agricultural fields at night.

The Sinya Mine area on the Tanzania-Kenya border is another important area for elephants (Fig. 1). This area provides permanent water in four abandoned clay mines of which one is fresh and the other three are salty. The water sources are surrounded by rings of vegetation ranging from fever trees near the water sources, Sueda shrublands (Sueda monoica), open woodlands of Acacia tortilis, and Acacia-Commiphora woodlands furthest from the water sources.   Seven of the GPS-collared elephants used the Sinya Mine area extensively during both the wet and dry seasons. The three bulls spent extensive periods of time at Sinya Mine during the dry season and less so during the wet season. The females typically used Sinya Mine as a transitory stop while moving between West Kili and Amboseli NP. Although there are no human settlements at Sinya Mine, the water source with freshwater is used extensively during the day by Maasai cattle herds throughout the dry season.

The Kitirua Concession Area (CA) across the border in Kenya southwest of Amboseli NP is another important area for elephants (Fig. 1). This open area is dominated by elephant grass (Sporoblus consimilis); Sueda shrublands and Salvadora shrubs (Salvadora persica). There is a small stand of fever tree woodland at Nadosoito on the Kenyan side, but it is fenced to exclude wildlife. There are no water sources in this area, but it was used extensively by seven of the collared elephants moving from Sinya Mine to Amboseli NP. There are no permanent bomas in this travel corridor, but the area is used extensively for cattle grazing during the dry season.

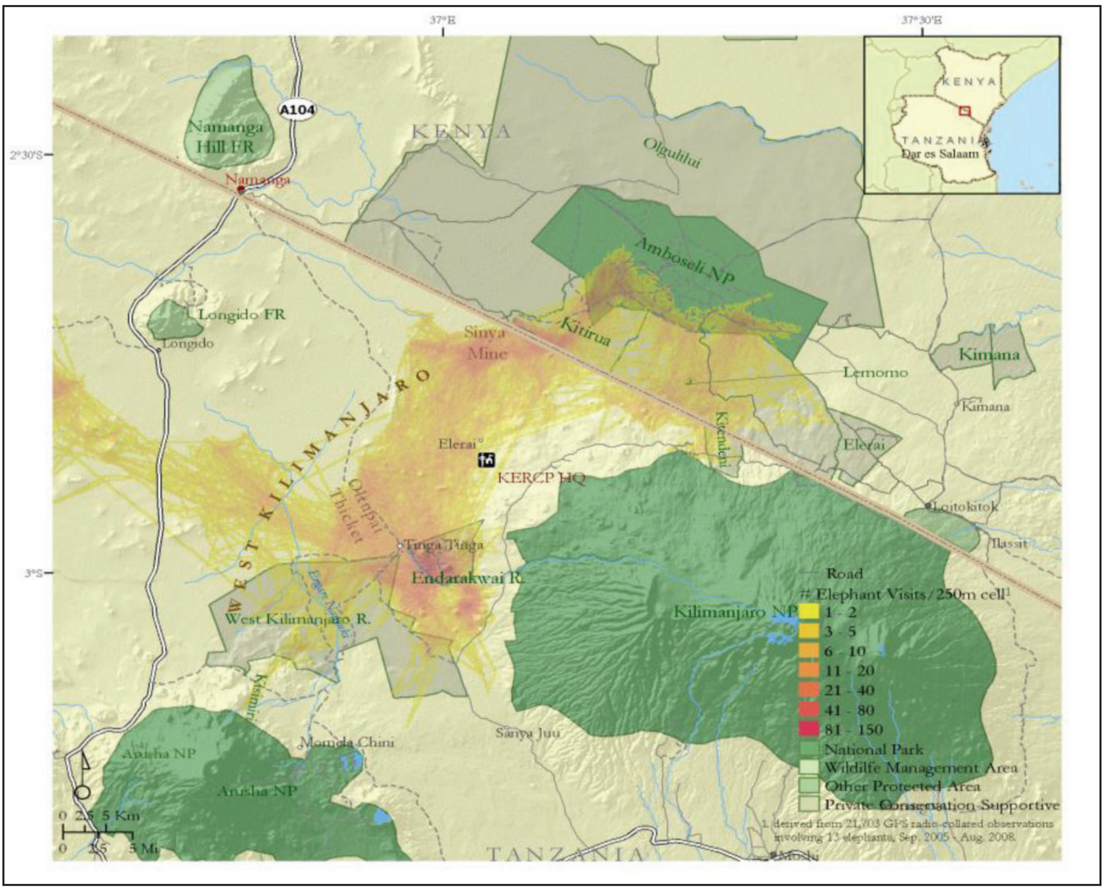

Figure 1. West Kilimanjaro region of northern Tanzania and Amboseli Basin of southern Kenya showing international border, protected areas, communities and important elephant habitats.

The proposed Lemomo CA south of Amboseli is an important area for elephants linking Amboseli NP to the Kitendeni Corridor and Kilimanjaro NP (Fig. 1). The area is characterized by dense stands of Acacia-Commiphora woodlands in the southern portion of the CA, rocky grazing lands to the north, and a small area of elephant grass around Imarba Village on the eastern side of the CA. Five of the collared elephants used this area extensively, especially during the wet season, as well as during the dry season for T21. The dense Acacia-Commiphora woodlands in the southern portion of the CA restrict cattle grazing throughout the wet season and early dry season. Human settlements and tourist facilities are concentrated to the north along the southern border of Amboseli NP.

DISCUSSION

The extensive transboundary movements of elephants between northern Tanzania and southern Kenya indicate that the elephant populations of West Kili and Amboseli NP constitute a single transboundary population. These observations contrast with earlier researchers (Afolayan, 1975; Western & Lindsay, 1984; Grimshaw & Foley, 1991; Moss, 2001) who reported that the Amboseli elephant population was distinct and rarely, if ever, dispersed from southern Kenya into northern Tanzania. This apparent shift in elephant movement patterns may be related to several factors relating to resource availability and humans. First, Western (2006) documented long-term changes in vegetation communities in the Amboseli Basin between 1950 and 2002. He documented the contraction of woodlands from 30% to less than 10% of the area with replacement by Suaeda/Salvadora scrub and grasslands. Further, he also reported the thinning of the dense bushlands fringing the northern portion of the Amboseli Basin and replacement by open bushlands, and that the permanent swamps increased > 3.5-fold in area within the basin. Western & Maitumo (2004) and Western (2006) attributed these losses of woodlands and expansion of grasslands and scrublands to elephants. Western (2006) reported that this large and continuing loss in habitat diversity throughout the basin caused sharp declines in browsing ungulates and some species extinctions (Western, 1989). In contrast, West Kili is dominated (65%) by thickets and shrubs (Kikoti, 2003), providing abundant browse habitat for elephants and other wildlife.

Human settlements, roads, agriculture and fences also expanded greatly around Amboseli NP since the late 1960s. Human populations increased from 85,000 to over 400,000 from 1969 to 1999 in the Kajiado District, greatly altering land use and land tenure patterns in the Amboseli Region (Campbell et al., 2000). In 2000, electric fences were constructed east of Amboseli NP to enclose irrigated, cultivated areas at Namelok (24 km of fence) and Kimana (38 km of fence) to reduce crop raiding by elephants (Kioko et al., 2008). These fences in combination with the extensive agricultural lands of Impiron farms and human settlements and roads pose barriers to elephant movements eastward from Amboseli NP to the Chyula Hills and Tsavo West NP (Okello, 2009). Similarly, Goguen (2010) reported that bomas, roads, and tourist facilities pose significant barriers to wildlife movements on the Olgulului-Ololorashi Group Ranch and western section of the Kimana Group Ranch that surround Amboseli NP. Consequently, increasing numbers of elephants from Amboseli NP may be dispersing southward into Tanzania.

In contrast to Western & Lindsey (1984) who reported that movements of elephants into Amboseli was primarily due to water availability during the dry season, most of our collared elephants had higher frequencies of transboundary movements into Amboseli during the wet season, a period when water is typically widely distributed across the region. The increased availability of grasslands in Amboseli reported by Western (2006) and the high utilization of grasses by elephants during the wet season (Kingdon, 1979) may partially explain these frequent movements to Amboseli by our GPS-collared elephants. Further, there may be less human disturbance of elephants by Maasai herders in Amboseli NP during the wet season because water is more widely distributed throughout the Amboseli Basin, thereby reducing the need to water cattle at the swamps within the park. Additionally, human disturbance may increase in West Kili during the wet season when many Maasai move their cattle herds from the Amboseli Basin into West Kili. Reportedly, the shallow, well-drained soils in West Kili (Kikoti, 2003) reduce the incidence of cattle hoof-related diseases associated with the poorly drained soils in the Amboseli basin (Maasai elders, pers. com.).

The extensive occurrence of GPS-collared bulls and females outside of protected areas (92%) underscores the critical importance of unprotected lands in supporting the elephant population in northern Tanzania and southern Kenya. Similarly, Douglas-Hamilton et al. (2005) reported that two elephants collared in Amboseli NP spent 60 and 90% of their time in unprotected areas in southern Kenya and northern Tanzania. With only 37% of elephant range within protected areas in Tanzania (Blanc et al., 2007), unprotected lands play a critical role in sustaining Tanzania's elephant population.

Conservation implications

Human settlements are expanding in many of the unprotected areas in West Kili and Amboseli Basin, resulting in increasing numbers of bomas, roads, agricultural fields, loss of woodlands and potential for human-elephant conflicts. Thus, more effective management of unprotected lands for elephants is needed to sustain elephants throughout the region. Land use regulations need to be developed for the Enduimeti WMA, and anti-poaching efforts expanded and coordinated with anti-poaching efforts throughout the region. Although the acquisition and management of the West Kilimanjaro Ranch and Endarakwai Ranch for conservation has protected important elephant habitats, anti-poaching efforts need to be expanded on these areas. Further, the Livestock Research

Center needs to be secured and managed for conservation to enhance protection of the Oltupai Thicket for elephants and other wildlife. The Research Center provides important woodlands for cover and feeding, and the Center is an important link with Siha Farms to the east, providing access to the western side of Kilimanjaro NP. Additional efforts are needed to reduce the illegal charcoal production occurring in the Oltupai Thicket, a critically important foraging and cover habitat for West Kili elephants. Securing the Kisimiri Corridor is another critical conservation measure needed. This corridor is a narrow (~1 km wide) valley providing the only remaining linkage between West Kilimanjaro Ranch and Arusha NP. Further, conserving this corridor will also reduce the potential of future human-elephant conflicts.

The Sinya Mine and adjacent Kitirua CA in southern Kenya constitute the most important link between West Kili and Amboseli NP. There is a critical need to establish a ranger post on the Kenyan side near Nadosoito Hill to facilitate regular anti-poaching patrols by the Amboseli-Tsavo Game Scouts Association. Further, these anti-poaching efforts need to be coordinated across the border with the Hifadhi Network in Tanzania.

Elephant use of the proposed Lemomo CA and connecting Kitendeni Corridor is the primary linkage between the southeastern corner of Amboseli NP and the northern border of Kilimanjaro NP. Although the Kitendeni Corridor is secure as the first conservation corridor in Tanzania (Kikoti et al., 2010), human activities in southern Kenya around Imalba and Mulududule villages and along the southern border of Amboseli NP severely restrict elephant movements moving in and out of Amboseli NP and contribute to high numbers of human-elephant conflicts. Land use regulations need to be developed by the Olgulului-Ololorashi Group Ranch to prohibit bomas from expanding into the two remaining pathways currently used by elephants. Working in collaboration with the lodges and their tourist operations, the community can encourage development away from these critical elephant pathways. Additionally, the group ranch could expand protection for these pathways by gazetting them as conservation corridors for wildlife and cattle grazing, similar to that accomplished for the Kitendeni Corridor by two Maasai communities in northern Tanzania (Kikoti et al., 2010). There is also a critical need to establish a ranger post on the Kenyan side near Lemomo Hill to facilitate regular anti-poaching patrols by the Amboseli-Tsavo Game Scouts Association. These patrols would also need to reduce illegal charcoal production occurring at Misigiyo Village. Further, these anti-poaching efforts need to be coordinated across the border with the Hifadhi Network in Tanzania.

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FUTURE OF WILDLIFE CONSERVATION IN TARANGIRE-MANYARA ECOSYSTEM, TANZANIA: THE CASE OF DISPERSAL AREAS ADJACENT TO LAKE MANYARA NATIONAL PARK

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ABSTRACT
Success in wildlife conservation within protected areas depends on sustainable management of adjacent dispersal areas and wildlife migratory routes, and support from adjacent communities. However, meeting these requirements is becoming a real challenge in many ecosystems. Manyara Ranch and community areas of Mto wa Mbu-Losirwa-Esilalei wards, spanning approximately 600 km2 are critical wildlife dispersal areas and important to the future of Lake Manyara National Park. We explore land usage, wildlife numbers and distribution and residents' perceptions on wildlife. The dominant land uses - agriculture and human settlement, occupy 68km2 (60%) of the community area we studied. Wildlife encounter rates (herds/km2) were lowest in the community area (0.4 herds/km2) compared to Manyara Ranch (1.64 herds/km2), and Lake Manyara National Park (2.0 herds/km2). The minimum distance wildlife kept from nearest human settlement was 197m in the community area. Over 50% of the residents in the dispersal area experienced conflicts with wildlife, largely elephants, primates, and leopards, lions and hyenas. Although residents in community area expressed overwhelming support (75%) for wildlife conservation, their views on the conservation status of some of the most common species found in the area conflicted with internationally known species conservation status. For example zebra, buffalo and wildebeest were believed by residents to be the most endangered species but not elephant, lions and leopards. While more effort is needed to secure the dispersal areas, the intricate relationship between humans and wildlife in the dispersal area need to be further explored with a view to make the area secure and more conducive for wildlife and to reduce human-wildlife conflicts. Education program(s) should aim at raising community awareness on species conservation status in the area.

Keywords: *dispersal area, human activities, protected areas, Tarangire-Manyara ecosystem, wildlife conservation status.*

INTRODUCTION

Insularization of protected areas has become recognized as a major threat to wildlife conservation globally (Newmark, 1993). For smaller protected areas, dispersal areas are necessary to provide adequate access to water, breeding sites, and feeding habitats for wildlife (Okello & Kioko, 2010). However, increasing human activities and associated land use changes around these protected areas are limiting the dispersal area for wildlife (Kideghesho et al., 2006; Western, 1998), resulting in impaired ecosystem function and structure (Bond, 2003; Hansen & DeFries, 2007).

To help alleviate the effects of habitat fragmentation, wildlife corridors exist to ensure that habitat connectivity within and between protected areas is maintained. Increased contact between humans and wildlife due to lack of sound planning for wildlife dispersal areas can result in negative interactions between residents in dispersal areas and wildlife (Zhang & Wang, 2003), with severe implications on household economics (Butler, 2000). The Tarangire-Manyara ecosystem faces a microcosm of human induced threats on the wildlife dispersal areas. Changes in pastoralist lifestyle from large scale pastoralism to semi-nomadism has led to intensification of grazing. Livestock has potential to displace wildlife in most habitats (Georgiadis et al., 2007). Human settlements cause ecological disturbances, influencing flora and fauna density and abundance (Morris et al., 2008; Wallgren et al., 2008). Increased human-wildlife conflict may impair conservation efforts (Hill, 2005). In the Tarangire-Manyara Ecosystem, many wild animal species are migratory, moving between protected areas through privately or communally owned lands (Tarangire Elephant Project, 2007). The area is also a tourist hotspot, with Lake Manyara and Tarangire National Parks generating over $3.2 million in gate revenues for Tanzania, and employing a significant number of local people (Sachedina, 2006).

The aim of this study was to assess the scale of human-wildlife interactions within the dispersal area adjacent to Lake Manyara National Park and the implications for wildlife conservation in northern Tanzania by analyzing the historical ecological changes, extent of habitat fragmentation, spatial distribution of land available for wildlife, and characteristics of human-wildlife conflicts. Understanding human-wildlife dynamics can be a useful tool for future planning to mitigate the insularization of Lake Manyara National Park.

MATERIALS AND METHODS

Study area

This study was carried out in the area comprising three different types of land uses with differing levels of management (Fig 1). Manyara National Park is a core protected area under the management of Tanzania National Park Authority (TANAPA) where no human development activities are allowed except for photographic tourism. Manyara

Ranch, which forms part of the Kwakuchinja corridor, is a semi-protected multi-use area under the management of a private land trust, Tanzania Land Conservation Trust (TLCT), and is managed to conserve wildlife and safeguard the interest of the pastoralist communities. The ranch has tourism operations as a source of revenue to complement wildlife conservation and livestock keeping. The community area lies between Manyara NP and Manyara Ranch, and is dominated by peri-urban development, livestock keeping, agro-pastoralism, and intensive crop irrigation in Mto wa Mbu-Majengo wards (Sumba et al., 2005). Recent years have seen growing tourism related investments in the Tarangire Manyara Ecosystem that have fueled rapid human population growth and associated booming of small town at Mto wa Mbu (Okello & Yerian, 2009). To the east of Mto wa Mbu are the Losirwa and Esilalei wards, areas mainly under extensive pastoralism.

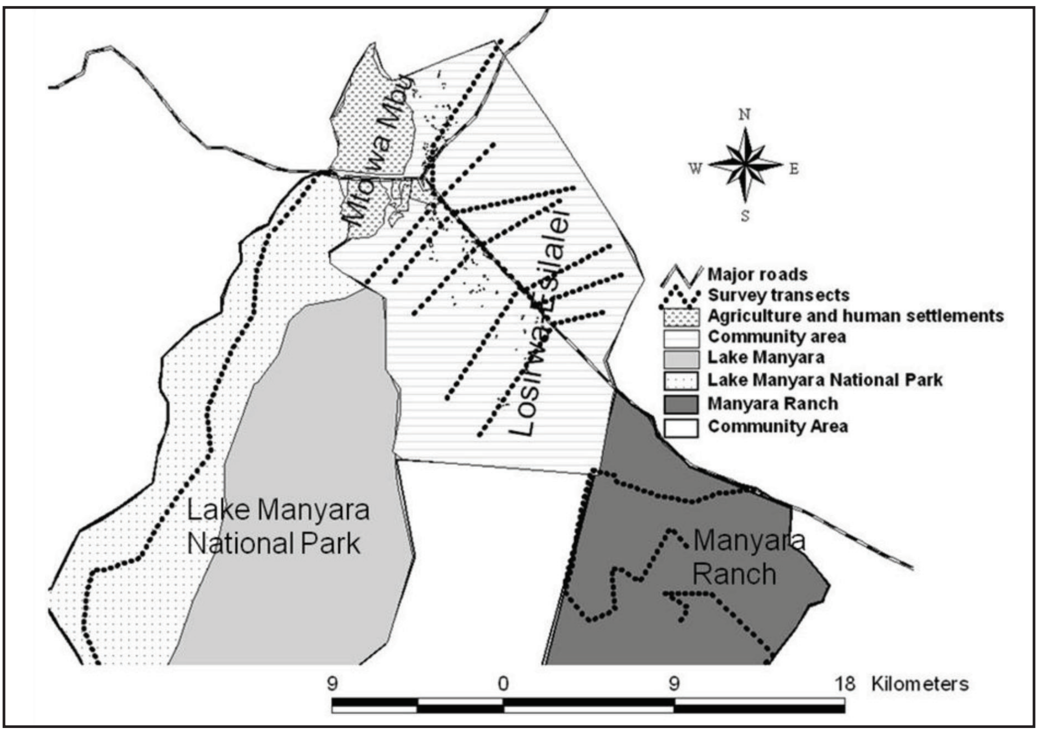

Figure 1: Study area including Lake Manyara National Park, Manyara ranch and adjacent community wildlife dispersal area in the Eslalei-Losirwa-Mto wa Mbu area

The study area experiences a tropical semiarid climate with bimodal rainfall ranging from 375-1250 mm/yr (Cohen et al., 1993); mean annual rainfall is 650 mm/yr (Prins, 1988). The altitude in the study area ranges from 950-2450 m above sea level (Sachedina, 2006). There is a diverse population of herbivore species including the African elephant (Loxodonta africana), wildebeest (Connochaetes taurinus), impala

(Aepyceros melampus), and Maasai giraffe (Giraffa camelopardis). The most common large carnivores include lions (Panthera leo), leopards (Panthera pardus), cheetahs (Acinonyx jubatus) and spotted hyenas (Crocuta crocuta). In the wet season, most wildlife move into dispersal areas in the communal land. Thus the study area is in the midst of a complex social-ecological system with high levels of interactions between wildlife and humans. Habitat types range from ground water forest in parts of Manyara National Park (Greenway & Vesey-Fitzgerald, 1969) to a mixture of woodland, bush grassland, shrub grassland, shrubland, and open grasslands.

METHODS

Large mammal numbers and distribution

Road vehicle counts for large mammals and ostrich (Struthio camelus) were performed in Lake Manyara National Park, Manyara Ranch and the adjacent community areas to determine wildlife numbers and distribution. When a mammal larger than a cape hare (Lepus capensis) was spotted, the time, Geographical Positioning System (GPS) coordinates (GPS map 76CSx, 1999, Garmin Ltd) for location determination, species, and total number of individuals, habitat type, distance to the nearest surface water, type of water body and the distance to the nearest human structure were recorded. Distances were measured using a Range Finder (Bushell© ELITE© 1500 Laser Rangefinder). Water body types included artificial pools or dams, ponds, rivers and lakes. Habitat types were classified as open bushland (with few scattered bushes or trees and maximum visibility of up to 100 m distance), closed bushland (dense habitat with poor visibility of less than 100 m), groundwater evergreen forest (green forest with tall trees more than 20 m high and interlocking canopy), wetland (any habitat within 200 m of a water source), and woodland (defined as stands dominated mostly by baobabs (Adasonia digitata), yellow fever (Acacia xanthophloea), Acacia.

Using vehicle road counts, transects of 2 km at 500 m intervals were used and mammals within 500 m on either side of the transect were noted. For the livestock count, GPS coordinates, herd size, species composition, herd spread (length and width occupied by the herd), habitat type, presence of herders and presence of dogs were recorded whenever livestock was spotted. Livestock species included goats (Capra aegagrus hircus), sheep (Ovis aries), cattle (Bos indicus), and donkeys (Equus africanus asinus).

Habitat fragmentation

In order to measure the extent of habitat fragmentation in the community managed areas, human structures categorized as farmlands, buildings, roads, public and social amenities (such as churches, schools, administrative areas, markets, tourist hotels and lodges) and traditional homesteads (bomas) were mapped. To determine the size and space occupied by each type of human structures and activities, a GPS was used to record the perimeter of the structures and activities by walking on the boundaries and recording coordinate locations at intervals.

Local residents' resource use and perceptions on wildlife

A structured questionnaire was administered to local farmers and pastoralists at the household level in community area. Households were stratified based on: distance from Lake Manyara National Park as pastoralists living adjacent (0-5 km) to Lake Manyara National Park, farmers living adjacent to Lake Manyara National Park (0-2 km), pastoralists living away (>8 km) from Lake Manyara National Park, and farmers living away (5-10 km) from Lake Manyara National Park. Interviews were conducted in Maa or Kiswahili with the aid of translators fluent in both languages and English. The basic information recorded included respondent's background information, extent and nature of human-wildlife conflicts, perceptions and knowledge of wildlife conservation, climatic and ecological changes. 137 interviews consisting of 33 respondents (24.1%) were farmers adjacent to the park, 36 respondents (26.3%) were farmers away from the park, 38 respondents (27.7%) were pastoralists adjacent to the park and 30 respondents (21.9%) were pastoralists away from the park. No more than two interviews were conducted per boma in the pastoral area of the interviews, and only one interview was conducted per home in the farming area. Interviewees were adult members of the household and generally the head of the household unless he/she was unavailable.

Statistical Package for Social Science (SPSS, Version 9.0 for Windows, SPSS Inc., 1999) was used for statistical analyses. A one-way ANOVA test was used to test if a significant difference existed among the herd sizes per km2 in Lake Manyara National Park, Manyara Ranch and community area. If there was a significant difference, a Tukey test was performed to determine which areas had significantly different herd sizes. A Pearson's Correlation test was used to examine if a correlation existed between encounter rate of human structures and wildlife encounter rate. Chi-square goodness of fit test was used to determine if there was a relationship between large mammal species and habitat type. Kruskal-Wallis test was used to test if large mammal group size differed in Lake Manyara National Park, Manyara Ranch and community area and across habitats. If large mammal species were found in only two areas, a Mann-Whitney Test was used to test if group sizes varied. Species diversity for Lake Manyara National Park, Manyara Ranch and community area was determined using Simpson's Diversity Index and the variance between the Simpson's Diversity Index values was determined Brower & Zar (1977).

Chi-square contingency test was used to determine relationships between responses and Chi-square goodness of fit test was used to determine if there was a significant difference among the responses. ArcGIS (ESRI, 2011) was used to map and calculate areas covered by human structures.

RESULTS

Large mammal numbers and distribution

Livestock was common in Community area, with a few herds observed in Manyara Ranch. Twenty species of large wildlife and five species of domestic stock were in the three areas (Table 1). Lake Manyara National Park had the highest wildlife species diversity (DS = 0.85) followed by Manyara Ranch (DS = 0.75), while community area had the least (DS = 0.70). Baboons (Papio anubis), common bushbuck (Tragelaphus scriptus), hippopotamus (Hippopotamus amphibious), blue monkeys (Cercopithecus nictitans) and common waterbuck (Kobus ellipsiprymnus) were only found in Lake Manyara National Park, while Lesser kudu (Tragelaphus imberbis), Grant's gazelle (Gazella granti) and Eland (Taurotragus oryx) were only observed in Manyara Ranch.

There was a significant difference in the overall number of wildlife herds encountered across the study area (F = 20.865, df = 88, P<0.05) with 2.00 ▯ 0.27SE herds/km2 in Lake Manyara National Park, 1.64 ▯ 0.28SE herds/km2 in Manyara Ranch and 0.45 ▯ 0.12SE herds/km2 in Community area (Fig 2).

Table 1: Number of large mammals and including Maasai Ostrich observed in Community area, Manyara Ranch and Lake Manyara National Park.

Species	Total	Community area	Manyara Ranch	Lake Manyara National Park
African Buffalo	331	3.6%	-	96.4%
Olive Baboon	312	-	-	100%
Banded Mongoose	9	-	100%	-
Blue Monkey	61	-	-	100%
Common Bushbuck	1	-	-	100%
Common Zebra	936	41.8%	44.1%	14.1%
Kirk's Dikdik	26	-	57.7%	42.3%
Cape Eland	33	-	100%	-
African Elephant	93	-	81.7%	18.3%
Maasai Giraffe	105	1.0%	49%	49.5%
Grant's Gazelle	53	-	100.00%	-
Cape Hare	2	100%	-	-
Hippopotamus	15	-	-	100%
Impala	585	16.2%	32.3%	51.5%
Lesser Kudu	1	-	100%	-
Maasai Ostrich	44	9.1%	90.9%	-
Thomson's Gazelle	183	82.0%	18.0%	-
Vervet Monkey	76	-	18.4%	81.6%
Warthog	71	-	2.8%	97.2%
Common Waterbuck	11	-	-	100%
White-Bearded Gnu	423	68.1%	0.9%	31.0%
- = None observed during transect counts				

Looking at individual species, there was no Thompsons gazelle seen in Lake Manyara National Park, they were only found in Manyara Ranch and in the dispersal area. There was a significant difference in the giraffe herds/km2 ($F = 6.82$, $df = 85$, $P = 0.00$) with the most being recorded in Lake Manyara National Park and least being recorded in the dispersal area. There was a significant difference between the mean Grant's gazelle herds/km2 ($F = 8.88$, $df = 85$, $P = 0.00$). Grant's gazelles (0.14 ± 0.06 SE) were only found in Manyara Ranch. There was also a weak, insignificant correlation between wildlife and livestock encounters ($r2 = -0.02$, $P = 0.23$).

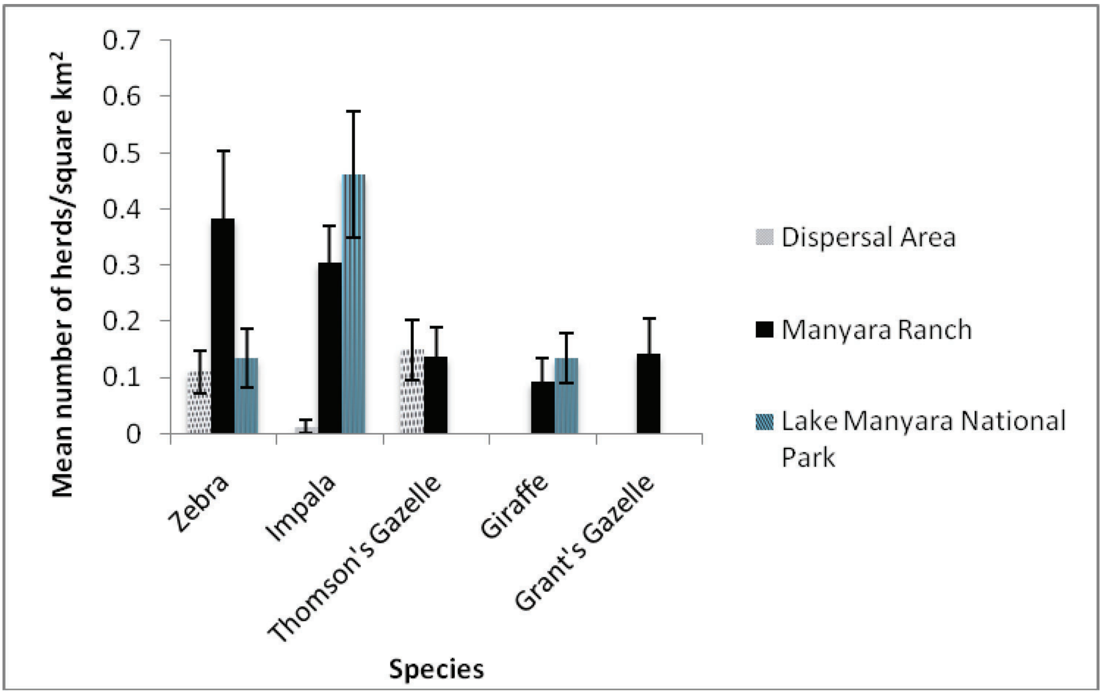

Figure 2: Mean herd/km2 for different species across the study area.

There was no significant difference in group size of zebra, wildebeest, impala and elephant. The average group size of zebra was slightly higher in Community area with 26.07 ± 7.72 SE individuals than in Manyara Ranch and in the Park (Table 2).

Table 2: Average group size of large mammal species in Lake Manyara National Park, Manyara Ranch and Community area (* Species not observed).

	Mean group size (mean±SE)			
Species	Lake Manyara National Park	Manyara Ranch	Community area	test result
Zebra	18.86±8.7	17.96±3.88	26.07±7.72	H(2) = 0.298, P = 0.861
Impala	12.54±2.90	10.5±2.73	13.57±4.63	H(2) = 0.122, P = 0.941
Thompson gazelle	*	4.71±1.48	13.64±6.89	U = 41.0. P = 0.932
Maasai giraffe	7.42±3.25	8.67±4.65	*	U = 19.5, P = 0.828
Wildebeest	26.2±16.77	4±0	20.57±6.82	H(2) = 0.131, P=0.937
Elephant	4.25±1.7	4.5±1.71	*	U = 15.00, P=0.864

Extent of human activities

Of the area mapped in community area (114 km2), human settlements and agriculture occupied a combined total of 60% km², with agricultural areas of Mto wa Mbu occupying 26% (30 km2) while human settlements took 33% (38 Km2) (Fig 3). The majority, 75 (68.8%) of livestock herds were accompanied by a herdsman who had 1.82 ± .11 SE dogs accompanying. There was a weak correlation between herd size and area occupied by the herd ($r2 = 0.11$, $P= 0.24$). The average area occupied by livestock herds was 891.85 m² ± 269.47 SE m², with the total area amounting to 102,563 m². There was no significant correlation between the wildlife encounter rate and the density of human structures ($r2 = -0.288$, $p = 0.068$, $N = 41$); however, no wildlife groups were encountered in areas with a density of human structures greater than 5 per km2.

Respondents' background information

The majority (53.7%) of respondents were aged 19-35 ($X^2 = 76.328$, df = 3, $p = 0.00$), while 2.2% were 15-18, 16.4% were 36-45 and 27.6% were older than 46 years. Females comprised of 56.2% while 43.8% were male. Respondents with formal education comprised 45.3% while 48.2% had gone up to primary school, and only 6.6% of respondents had attended secondary school. Maasai tribe comprised 52.6% of all respondents, with the remaining 47.4% non-Maasai. The main economic activity of the respondents (48.1%) was agriculture ($X^2 = 13.733$, df = 2, $p = 0.001$), compared to 28.1% of respondents were pastoralist and 23.7% agro-pastoralists. The mean number of years lived in Community area was 22.38 years, while the majority of respondents (53.3%) had lived in the area for less than 20 years. Majorities (25.6%) of respondents have lived in the area between 21 and 40 years, 17.8% have lived in the area between 41 and 60 years and 3.3% have lived in the area for more than 61 years. A variety of reasons were given for moving to the Mto wa Mbu area ($X^2 = 5.370$, df = 2, p =

0.068). Some reasons for moving into the area included: ecological (44.6%), economic (29.3%), and family (26.1%). Ecological reasons included better farming or grazing land, economic reasons included searching for employment and family reasons including getting married or following other family members.

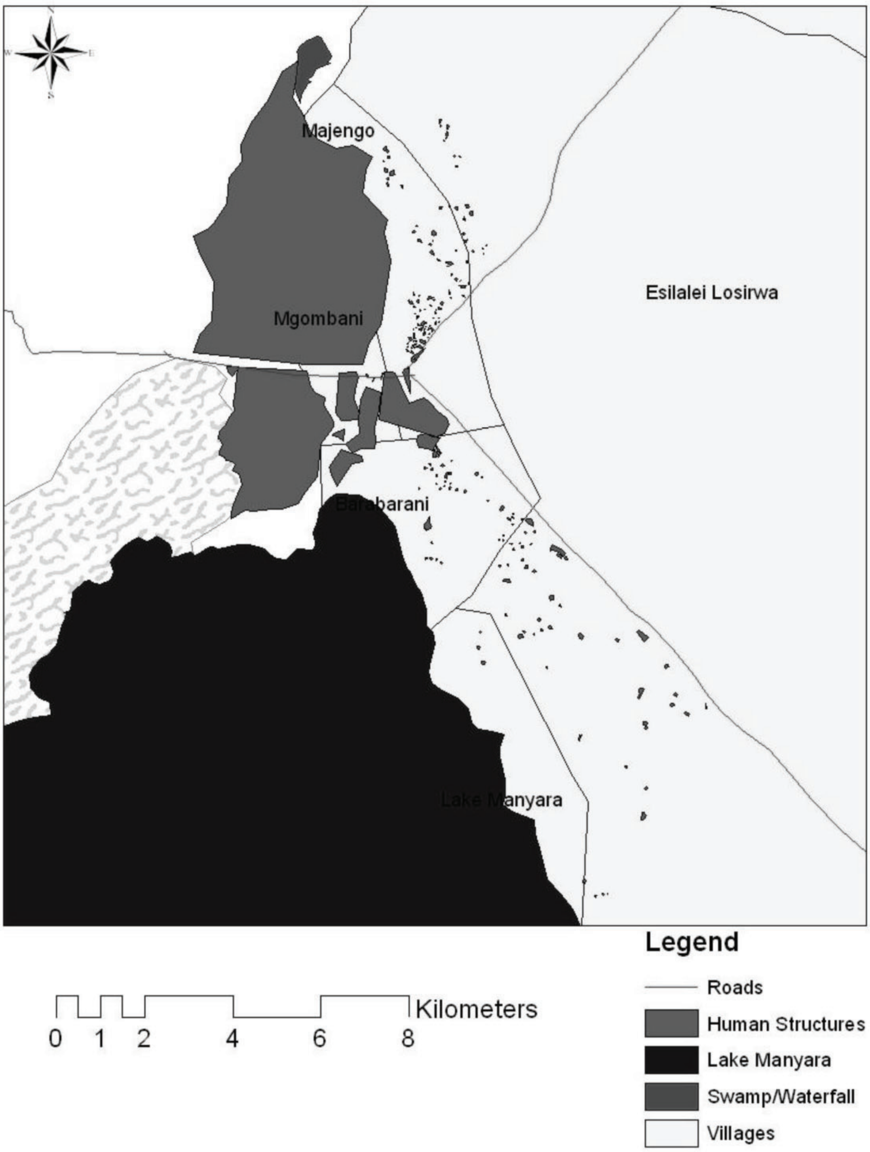

Figure 3. Human structures in the study area

Resource use and environmental changes

The majority of respondents (80.3%) had piped water and got firewood from woodlands and bushlands adjacent to Lake Manyara National Park (73.1%). The majority of respondents watered their livestock from artificial wells (32.0%) or dams (27.2%) ($X^2 = 25.301$, df = 4, $p < 0.05$). The community area is important for residents' livelihood, 53.3% of respondents used Lake Manyara for fishing ($X^2 = 13.520$, df = 2, $p < 0.05$), 88.7% used the lake grassland for grazing, 50.7% used the riverine habitat for irrigation ($X^2 = 58.059$, df = 3, $p<0.05$), and 58.0% used the Acacia xanthophloea for firewood collection ($X^2=94.301$,df=3,$p < 0.05$).

The major environmental changes witnessed by the residents was drought (51.5%), land degradation characterized by deforestation, drying of rivers and reduced crop production (12.7%), although 12.7% said they observed no change ($X^2 = 76.285$, df = 3, $p < 0.05$). The main reason for the drying of rivers was said to be drought, while 24.8% of respondents attributed it to poor agricultural practices. The frequent drying of Lake Manyara was generally attributed to climate change (68.3%) while 17.3% gave no explanation. Most respondents (56.7%) could not give an explanation why the area was experiencing reduced rainfall, 18.4% attributed reduced rainfall to climate change and 17.7% attributed it to deforestation.

Crop and livestock predation by wildlife

Out of all of the respondents, 48 (43.6%) people reported that they experienced crop raiding all the time, 34(30.9%) reported they occasionally did, while 28(25.5%) reported they rarely experience crop raid. There was a significant difference among the species the community listed as most problematic to crops ($X^2 = 24.46$, df = 4, $p < 0.05$). The most problematic wildlife species were reported as elephants and primates. Of the pastoralists interviewed, 16 (27.6%) said that predation on livestock was always a problem; 19 (32.8%) said it was occasionally a problem, and 23 (39.7%) said it was rarely a problem. Among livestock keepers, 27.0% reported leopards, 33.6% reported lions, and 32.2% reported hyenas as the most problematic ($X^2 = 1.191$, df = 2, $p = 0.55$).

Among the animals living in the study area, inhabitants feared elephants (38.0%) and lions (30.7%) the most ($X^2 = 26.080$, df = 3, $p < 0.05$). Of the farmers interviewed, 26 (37.7%) said they do not like elephants and 34 (49.3%) said they liked elephants to a great extent; 38 (55.1%) said they did not like baboons, 6 (8.7%) said they liked baboons to some extent, and 25 (36.2%) said they liked them to a great extent. There was a significant difference among the responses for how the respondents deal with problem animals to crops ($X^2 = 38.82$, df = 3, $p < 0.05$). The majority of respondents said they either scare animals away (42.2%) or call game wardens (26.7%). Of the pastoralists, 34 (97.1%) reported that they disliked hyena, and 28(77.8%) reported to disliked lions. There was a significant difference among the measures the community takes to deal with predatory animals ($X^2 = 31.41$, df = 3, $p < 0.05$). The most common response was to kill them (42.6%) or scare them away (41.2%). There was a significant relationship ($X^2 = 15.45$, df = 2, $p < 0.05$) between the frequency of the incidence of crop destruction and the location of the farmers. Farmers adjacent to the park had a significantly higher frequency of problems, with 45.5% reporting that animals were always a problem, compared to only 10.0% of farmers living away from the park. Although more pastoralists living in close proximity to the park stated that they always had problems with wildlife (76.0% compared to 50.0%), no significant relationship was observed in frequency of livestock predation and proximity to the park ($X^2 = 4.87$, df = 2, $p = 0.08$). There was also no significant relationship between pastoralists' opinion on wildlife conservation and what they perceived to be the best solution to human-wildlife conflicts ($X^2 = 8.39$, df = 4, $P = 0.08$). However, most pastoralists (67.4%) said that they did not know any solution for human-wildlife conflict in the area.

Support for conservation and views on wildlife

Relationships between respondent and their background are summarized in table 3. There was no significant relationship between age and support for wildlife conservation ($X^2 = 0.73$, df = 3, $P = 0.87$). There was a significant relationship between gender and support for wildlife conservation with 50 (83.3%) men supporting wildlife conservation as opposed to 47 (65.3%) women supporting wildlife conservation ($X^2 = 5.48$, df = 1, $p < 0.05$). There was a significant relationship between the level of education attained and support for wildlife conservation ($X^2 = 26.77$, df = 2, $p < 0.05$). There was a significant relationship between ethnic tribe and support for wildlife conservation with 62 (95.4%) non-Maasai and only 35 (52.2%) Maasai supporting wildlife conservation ($X^2 = 31.52$, $p < 0.05$). There was a significant relationship between main economic activity and support for wildlife conservation with 62 (95.4%) farmers supporting wildlife conservation ($X^2 = 33.40$, df = 2, $p < 0.05$). There was a significant relationship between supporting environmental conservation and wildlife conservation ($X^2 = 23.11$, df = 1, $p < 0.05$). Most of the people (99.0%) who supported wildlife conservation also supported environmental conservation. There was not significant correlation between the respondents' views of the importance of Lake Manyara and their choice of supporting environmental conservation ($X^2 = 0.40$, df = 1, $P = 0.82$).

Community preference for wildlife species and their views on species status

There was a significant difference in community views on species conservation status ($X^2 = 64.84$, df = 5, $P < 0.001$). Zebras were believed to be the most the most endangered species by respondents (23.7%) while 18.4% did not know the conservation status of wildlife species ($X^2 = 64.842$, df = 5, $p < 0.05$). Community member's likeness for a range of species differed significantly ($p < 0.05$). The species reported to be mostly preferred were Wildebeest (76.5%), zebra (72.2%), Giraffe (89.1, Gazelles (90.9%) and birds (79.0%) based on the frequency of responses to I don't like or like the species question. Among the species disliked, only 33.30% liked Baboons, 24.4% Hyena, 43.9% elephants, 42.2% Porcupine, 41.8% Bush pig, 41.7% Lion and 39.9% Hippopotamus.

Table 3: Community support for wildlife conservation.

Characteristic	Support Wildlife Conservation	Summary of Result
Education Level	$\chi^2 = 26.77$, df = 2, $p < 0.05$	Those with higher education levels had more support for wildlife conservation
Economic Activity	$\chi^2 = 33.40$, df = 2, $p < 0.05$	Agriculturalists (95.4%) support wildlife conservation more than agro-pastoralists (55.2%) and pastoralists (47.2%)
Ethnicity	$\chi^2 = 31.52$, df = 1, $p < 0.05$	Non-Maasai (95.4%) support wildlife conservation more than Maasai (52.2%)
Age	$\chi^2 = 0.73$, df = 3, p = 0.87	No significant relationship
Gender	$\chi^2 = 5.48$, df = 1, p = 0.02	Men (83.3%) support wildlife conservation more than women (65.3%)

DISCUSSION

The ecological function of the dispersal area for Lake Manyara National Park and Manyara Ranch is currently threatened by encroachment of human activities and structures. Both Lake Manyara National Park and Manyara Ranch had significantly higher encounter rates for all wildlife herds compared to the dispersal area, suggesting that wildlife is less abundant in the dispersal area than within the protected areas. The presence of higher wildlife encounter rates demonstrates the importance of the park and the ranch as critical habitats for wildlife in the Tarangire-Manyara Ecosystem. Considering that this study was conducted during the wet season when many animals tend to move outside of the parks to access water and food resources, the low encounter rate of wildlife in the dispersal area may indicate the exclusion of wildlife from these areas by humans and/or human activities (Georgiadis et al., 2007; Western, 1998). Species like zebra and Grant's gazelle are more resilient to livestock-dominated landscapes than species such as eland, hartebeest, impala, giraffe, waterbuck and buffalo (Georgiadis et al., 2007). This supports our findings, as eland, lesser kudu, waterbuck, and a large portion of giraffe and buffalo were only observed in one or both of the protected areas. One of the potential causes of the fewer species in the area is an increase in human activities that has degraded the habitat in the dispersal area. Increasing human settlements causes intensified pressures on dispersal areas as depletion, degradation and fragmentation of habitats (Kushwaha & Hazarika, 2004). Over 70% of residents rely on agriculture or agro-pastoralism as their main economic activity, which is more detrimental to the ecosystem's structure and has a major effect on the distribution and abundance of wild ungulates (Fritz et al., 2003).

As a key area for migratory species such as wildebeest, zebra and elephants (Sachedina, 2006), habitat connectivity is essential to maintaining the ecological viability of protected areas such as Lake Manyara National Park, Manyara Ranch and Tarangire National Park. Almost a quarter of the area mapped was taken up by human structures and activities that directly displace wildlife habitats. As more people move into the area in search of farmland, habitats are increasingly disappearing. Although about 75% of the land mapped in the study area is not occupied in Community area, associated human activities can have significant effects on wildlife ecology as the presence of humans and livestock alone can deter wildlife from using that area (Georgiadis et al., 2007). Furthermore, human presence is highly associated with habitat degradation through activities such as tree cutting (Kiringe & Okello, 2005). Residents cut trees for firewood, charcoal burning and to clear land for cultivation. Since many people do not have enough money to buy essential items like firewood, the main source of energy for cooking and heating in Tanzania, they turn to the surrounding area for these resources (Kideghesho et al., 2006). For habitats like the A. xanthophloea forest, which is heavily utilized by the local people for firewood, charcoal and building materials, human activities pose a major threat to wildlife species that rely on those habitats. Riverine thickets, one of the prime habitats reduced by farming provides resources like cover and dry season habitat for wildlife (Fritz et al., 2003). Increased resource extraction could severely hamper biodiversity supported by an area (Stuart et al., 1990).

Conservation in the Tarangire-Manyara Ecosystem also faces the challenge of gaining community support. Humans live in close proximity to both Manyara Ranch and Lake Manyara National Park, which lead to human-wildlife conflicts. Most farmers experience crop damage by wild animals. Proximity of farmlands to Lake Manyara National Park has increased the incidences of crop damage, mostly by elephants and primates. These findings are consistent with other studies (e.g. Hill, 2005) that found proximity to protected areas to influence the frequency of crop raiding. Lions, leopards and hyenas were the animals most commonly cited as predators on livestock, matching the results of similar studies in which retaliatory killings were fairly common in for lions, leopard and hyenas due livestock predation (Kissui, 2008). The farmers said that they would scare away crop raiders or call wildlife management personnel in contrast to the pastoralists who suggested that they would kill the problem animal. The suggested use of lethal response to livestock predation has severe implications for conservation of top carnivores such as lions and leopards that are internationally endangered (Henschel et al., 2008). Incidentally, there is minimal awareness of the conservation status of wildlife species. Residents' perceptions of whether a species is endangered or not is more linked to the effects of the species on their socio-economic livelihood, particularly crop or livestock predation. The species viewed positively were those associated with minimal or no socio-economic consequences on their livelihoods. Awareness education can be instrumental for the community members to understand the complex social-ecological dimensions of natural resource conservation.

The higher support for conservation in men than women is probably related to the level of education attained, as women were not as educated as men. Although pastoralist activities and Maasai are generally thought to be more conservation friendly than agriculturalists (Kioko et al., 2006), their indifference to wildlife conservation in the Community area may be due to changing customs in the Maasai culture, and their negative interactions with wildlife (Kuriyan, 2002).

The underlying dynamics between wildlife and humans in the Lake Manyara region have implications for managing wildlife associated with Lake Manyara National Park. This study gives several recommendations that may enhance wildlife conservation in the area. These include:

a)Conservation programs

i. Wildlife conservation education programs should be enhanced particularly target the threat facing specific wildlife species.
ii. Operationalisation of Man and Biosphere Reserve should be strongly promoted in Lake Manyara region.
iii. Harmonization of agriculture and development in Lake Manyara basin so as to promote.

b)Research recommendation

i. Maintenance of long-term monitoring of trends of wildlife such as ostrich, lion, wildebeest and elephants.
ii. Initiation and continuous long-term monitoring of human activities within the dispersal area for Lake Manyara area.

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DISTRIBUTION AND POPULATION STATUS OF AFRICAN WILD DOGS (*LYCAON PICTUS*) IN THE LOLIONDO GAME CONTROLLED AREA, TANZANIA

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ABSTRACT

African Wild dogs (Lycaon pictus) are the most endangered species compared to Ethiopian wolf (Canis semiensis). They went locally extinct in many areas in Africa partly due to persecution. The study aimed at establishing the status and distribution of the wild dog in the area. In 2009, diurnal random search was used to record the wild dog sightings in the LGCA. All sightings were geo-referenced and their total numbers in a pack were counted. From these sightings we were able to produce their distribution map in the LGCA. Sightings of the wild dogs in the LGCA are still common in the northern part of the area, moderate at the central part and relatively fewer in the southern part. The northern part has more wild dogs' sightings due to the presence of their favourable habitats which are woodland and rocks outcrops with hills. Low human disturbances to wild dogs has created conducive environment for them utilizing the area and hence attract more tourists to visit the area, to see them. On average, the pack size was estimated to be (9.01 ± SD 5.73 (CI, 0.16; ▯ = 0.95) at a density of 0.19 dogs/km2. The observed wild dogs' packs ranged from 1 to 30 individuals. Packs of three individuals were sighted frequently in the area. Therefore, there is a need to establish their home range to ensure their effective management in the area.

Key words: *African wild dog, distribution, population status, Loliondo Game Controlled Area*

INTRODUCTION

African wild dog (Lycaon pictus) is among the endangered large carnivores in the world (Sillero-Zubiri et al. 2004; Woodroffe et al. 2005; Woodroffe et al. 2007). Historically, they were distributed all over sub - Saharan Africa (Fanshawe et al.

1991; Woodroffe et al. 1997). In Africa, over the past decades wild dog numbers and distribution were declined due to habitat loss as well as persecution (Lindsey et al. 2004). The species has declined across their former range and they are now extinct in 25 of the 39 countries in which they were formerly recorded (Woodroffe et al. 2004). Recently wild dog resident population occupy only 7% of their former historical range (IUCN/SSC 2008). However, their occupancy is still restricted outside to protected areas. In fact, wild dogs occurs at lower population density than other competing carnivores, thus they are subjected to edge effect due to their wide ranging behaviour (Creel and Creel 2004; Woodroffe 2010). As a result larger protected areas are required to support viable wild dog population than the rest of large carnivore species (Creel and Creel 2004).

In Tanzania wild dogs were distributed in most of protected areas, with the largest population remaining in the Selous Game Reserves than other protected areas (Creel and Creel 2004). Basically, their distribution is restricted outside the protected areas (TAWIRI 2009). Formerly, the Serengeti ecosystem supported a viable population of African wild dogs before went locally extinct inside the Serengeti National Park in early 1990s (Burrows 1994). The population were mostly recorded on the grassland with most pack located on the plains. With all studies conducted in the country wild dog were never abundant (Creel and Creel 2002). Although the highest wild dog densities have been recorded in wooded savannah (Creel and Creel 2002), populations have been recorded in habitats as diverse as short grasslands, montane forest (Dutson and Sillero-Zubiri 2005) and mangroves. Before, went locally extinct in the Serengeti National Park they were seen even on the plain.

Today, wild dogs remain uncommon even in essentially less disturbed wilderness, apparently due to competitions with larger carnivores such as lion and hyena, and livestock predation (Mills and Gorman 1997; Creel and Creel 2004; Woodroffe et al. 2005; Woodroffe 2011). Although the species occurs in a wide range of habitats and can persist in a wide array of environmental conditions as long as preferred preys are available (Woodroffe et al. 2004). Before their recent population decline in the Selous Game Reserve, packs of up 100 animals had been recorded (Creel and Creel 2002). However, the average pack sizes recorded in most studies varies and presumably less than ten animals of unrelated male and female (Fanshawe et al. 1997; McNutt et al. 2008). Their distributions have been investigated throughout the African continent, together with their habitats, area requirements, diet, and behavioural aspects of its ecology (Creel and Creel 2002). Over past five years, wild dog populations have been constantly monitored in most of their range where they occur in the eastern part of the Serengeti ecosystem. However, scant information is available on their status and distribution. Therefore, this paper highlights recent information on their distribution, density and population structures in the Loliondo Game Controlled Area (LGCA).

METHODOLOGY

Study area description

The study was conducted in (LGCA), which falls within the Serengeti ecosystem in northern Tanzania. The (LGCA) (Fig. 1) lies between latitudes $2^{0}5'00''$-$2^{0}2'60''$S and longitude $35^{0}61'67''$-$35^{0}37'00''$E. It encompasses an estimated area of 4500 km2. Currently, human population density of Ngorongoro district is estimated at 176607, of which 85684 are males and 90923 are females. The estimate is computed using 4.5% annual growth rate (NDC 2009). Human activities such as settlement, small scale agriculture (13%), pastoralism (80%), tourism, and licensed hunting are permitted in the area (Homewood et al. 2001; NDC 2009).

Generally the climate is warm and dry, coolest from June to October, with a mean annual temperature of 20.8°C, which is often less than the diurnal variation (UNEP 2008). The average annual rainfall varies between 400mm and 600mm (Homewood et al. 2001). However, LGCA exhibits a bi-modal rainfall pattern with peaks occurring in December and April and a total of 400 – 1200mm per annum (Holdo 2010). The vegetation in LGCA varies from short grass plains to forest (Ojalamini, 2006; Sinclair et al. 2002). It is an important part of the semi-annual migratory route of millions of wildebeests and other ungulates northward into the Maasai Mara Game Reserve in Kenya between April and June, and returning southward between December to January every year (Holdo 2010).

Data collection

Diurnal random searches of wild dogs were conducted in areas historically known to have wild dogs to determine their distribution and population status. These searches were made by a team comprising of the researcher and enumerators (persons trained to locate wild dogs and make records). Pack sizes, age and sex of sighted individuals and GPS position were recorded for each pack encountered. Positions were recorded with the aid of a hand held Global Positioning System tool (GPS–Garmin 12) for mapping distribution. Photographs were taken using a high resolution camera for subsequent individual/pack identifications (IDs). A binocular was used to aid determination of pack sizes and individual/pack identification members where possible. Also, habitat/vegetation types were identified, and den sites and number of pups together were recorded. Secondary data were obtained from unpublished reports and journal publications at Tanzania Wildlife Research Institute (TAWIRI) and elsewhere.

Data Analyses

Data from random searches were collated in ArcGIS 10 (ESRI 2010) to map spatial distribution of the packs and habitat types for the wild dogs. According to Silverman (1986), for a random point/location for wildlife Kernel density estimation (KDE) in ArcGIS was used to estimate the density of African dogs. Data on population sizes of African wild dogs were summarised and analysed using Statistical Package for

Social Science (SPSS) manufactured by SPSS Inc., 233 South Wacker Drive, Chicago, USA.

RESULTS

Spatial distribution of African wild dog

Wild dogs were sighted within and outside LGCA (Fig. 2) and their sightings in various habitat/vegetation types were laid on the map (Fig. 3). Sightings outside LGCA consisted of one sighting in the Maasai Mara, Kenya and five sightings in Ngorongoro Conservation Area (NCA).

During the wild dog diurnal random searches, five categories of habitat were recorded and sightings varied in each habitat type ($\chi^2 = 43.9$, d.f. = 4, $\rho < 0.001$, Fig. 4). The sightings were overlaid on the vegetation types to show the wild dogs sighted in different habitat types (Fig. 5).

Population size and structures of wild dogs

During the diurnal random searches for African wild dogs, a total of 8 packs were recorded in the area and given names depending on the pack's place of residence. The Tinaga pack was found to consist of 19 adult dogs whereas the Losoito pack in the central part of Loliondo had 15 sub adult dogs. Also, six den sites were found with the number of pups ranging between two and four (Table 1) making a total of 132 individuals. The size of known packs ranged from 4 to 25 individuals with an average pack size of 16.5 animals. The pack sizes of known and unknown packs pooled together varied from 1 – 30 with average packs sizes of 9.01 (SD ± 5.736, CI, 0.16; $\infty = 0.95$). However the density for wild dogs was 0.19 animals/km2 for the whole surveyed area.

DISCUSSION

Spatial distribution of African wild dog

Wild dog were reported frequently from most of the villages in LGCA. In terms of their sightings, wild dogs were found concentrated mostly on the northern part of the LGCA. But they were sparsely distributed in the central part and scattered in the southern part. The order and magnitude of sightings of wild dog packs in different vegetation types of LGCA with most sightings in the woodlands (Fig. 4) are comparable to findings in Selous Game Reserve whereby wild dogs were also found to prefer woodland and bushland due to good cover (Creel and Creel 2004). However, sightings of the same wild dog packs in LGCA and NCAA, Tanzania and Maasai Mara, Kenya suggest that wild dogs in Loliondo can also use other areas of the eastern part of the Serengeti Ecosystem.

Habitat variation in LGCA (i.e. woodland, shrubland, bushland and anthropic landscapes) in combination with hills and rock outcrops possibly contribute to the tendency of wild dogs to concentrate more in the area. In other studies showed that, in Ethiopian Montane forest and East African mangrove in Ijara–Lamu in Kenya are one of ecological habitat uniqueness of wild dogs confirmed to occur (Dutson and Sillero-Zubiri 2005; IUCN/SSC 2008). Other factors could be the influence of wildebeest migration that occurs between December and May every year on the southern part of Serengeti ecosystem (Holdo et al. 2010). The migrating animals could be a good source of food supply to the wild dogs in the area. Contrary, study conducted in Hwange National Park, north-western Zimbabwe reported wild dogs to occur most in deciduous tree savanna, which constituted about 45% of the entire range (Rasmussen et al. 2008). Nevertheless, other findings reported that wild dog can coexist with people only under right circumstances such as high density of prey ungulates (Treves et al. 2004), low densities of domestic dogs and human (Woodroffe et al. 2004; Creel and Creel 2004), low density of hyenas and lions. Therefore, their occurrence in any area draws attention to their conservation. LGCA which has a remnant population is among the remaining core areas in the Serengeti ecosystem with wild dogs.

Population size and structures of wild dogs

This study reports eight known wild dog packs, with a total of 132 individuals. This population size is higher compared to previous estimates for wild dog in the early 1990s in the Serengeti National Park (Burrows 1995). For the case of the Maasai Steppe, which was reported to have only 8 packs (n = 70 individuals) is lower than what has been reported in this study (TAWIRI 2009). According to IUCN/SSC (2008), Katavi had 17 packs making 200 individuals; Kigosi-Moyowosi 33 packs making 400 individuals; Rungwa-Ruaha 35 packs making 500 individuals and Selous 50 packs constituting 880 individuals this is probably higher as compared to our finding. The present study on both known and unknown packs in LGCA range from 1 to 30 individuals with average pack size of 9.10 ± SD 5.70 (n = 82) which does not concur with the other findings (Somers et al. 2008). In Luangwa protected area complex (48180 km2) in Zambia probably holds the second largest wild dog population in Africa with mean pack size of 8.80 ± SD 5.10 (n = 24) with a pack size ranging from 1 to 27 individuals (Somers et al. 2008). Similarly, wild dog packs sizes in Northern Botswana varied from 2 to 30 adults, with an average pack size of 10.40 ± SD 5.40 (n = 84) (McNutt and Silk 2008). The lower mean pack size in this study contributed by communities disturbing the dogs so the dogs dispersed widely. However, community have no idea about the number of packs seen in the area due to inability to recognize individuals within various packs. Results of this study therefore correspond to previous report in the same ecosystem (Burrows 1995) that wild dogs are still seen in small pack sizes. The current recorded population size of wild dog is larger compared to what has been reported previously by Masenga and Mentzel (2005). However, the observed increase in pack sizes is linked to relatively lower carnivore populations in the LGCA (‘unpublished data’). In line to this, during the study period there were no wild dog recolanization inside the

Serengeti National Park. This is probably due to increased hyena and lion numbers in the park causing high interspecific competition (Woodroffe et al. 2004). The overall wild dog density (known and unknown packs) in this study area was 0.19 animals/sq km. By comparison, the density of adult wild dogs was 0.0195 adults/sq km which is relatively lower than what has been recorded in Selous Game Reserve, 0.04 animals/sq km (Creel and Creel 2002) and 1.6 adults/sq km in Hluhluwe-iMfolozi Park (Somers et al. 2008). However, the adult population density on the Serengeti plains over 13 years averaged 0.01 animals/sq km (Burrows 1995) which is lower than what has been recorded in this study.

CONCLUSION

These findings indicate that, the spatial distribution of wild dogs formed an access for wild reappearance in the Serengeti ecosystem. Although, the nature of the wild dogs to prefer more woodland habitat type that may obscure the visibility of the animal when searched by the people. Also the nature of protected area allowing the co-existence of mankind and wildlife in the natural settings poses a challenge to wild dogs sighting. Thus, most of these sighting were not close to human settlement (i.e. in areas close to human settlement such Sonjo area less sighting reported compared to Maasai area with a vast land unoccupied by human).

From this study it is not easy to draw up conclusion of the small pack sizes recorded during the diurnal random searches. However, in-depth information such as (pack recruitment, birth and death rate within and among pack members) is required to explain the presence of the low population sizes. The information provided shows that, the wild dogs in the LGCA are magnificent carnivores among others as they had not been sighted in the Serengeti National Park which has potential for tourist during the study period.

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USING NON-INVASIVE METHODS TO INVESTIGATE FACTORS AFFECTING THE SUCCESS OF THE BLACK RHINOCEROS: EXAMPLE FROM ADDO ELEPHANT NATIONAL PARK, SOUTH AFRICA

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ABSTRACT

Non-invasive faecal hormone analysis is an effective method for monitoring and increasing our knowledge of the health and reproductive success of wild populations. For critically endangered and slow breeding species, it is important to understand the factors that limit population growth. Addo Elephant National Park (AENP) has 70% of South Africa's southwestern subspecies of black rhinoceros (Dicerosbicornisbicorn is). For 3 years, we have been validating non-invasive field techniques for monitoring gonadal (progestin and androgen) and adrenocortical (glucocorticoid) activity in black rhinos from two sections of AENP. Camera traps were placed at rhino middens to identify individuals and facilitate collection of samples. Fresh faecal samples were collected, processed and analyzed for pregnancy on-site and sent to the United States for androgen (FAM) and glucocorticoid (FGM) metabolites analyses. Approximately, 250 samples were collected from known individuals (21 males; 22 females). Results demonstrate that males and females had similar ($P>0.05$) FGM concentrations; however, individuals in the section of AENP with the highest number of elephants and tourists had higher ($P<0.001$) FGM concentrations compared to the section with fewer elephant and tourist. Concentrations of FGM were lower ($P<0.01$) in the winter for both AENP sections. Pregnancy was accurately diagnosed in 100% ($n = 7$) of females with faecal progestin concentrations seven-fold higher ($P < 0.001$) in pregnant compared to non-pregnant rhinos. For males, FAM was higher ($P=0.006$) in summer and spring months and lowest in the winter. A similar pattern for progestin was observed in the females ($P=0.012$) with lowest faecal progestin concentrations in the winter. With validated, non-invasive monitoring methods, our long-term goal is to establish a multi-year, health monitoring program to investigate the relationship among black rhino hormonal activity, parasitic infection rates and varying abundance of mega-herbivores, predators and humans. Results will be used to facilitate management decisions for black rhino conservation.

INTRODUCTION

In the 1700s, the black rhinoceros (rhino; Dicerosbicornis) population in Africa was estimated at 850,000; however, its horn has been the target of poachers and by 1992 only approximately 2000 were left in the wild. Currently, the black rhino numbers have doubled to 4,880 individuals even though poaching has been on the rise (21.6% higher in 2011 compared to 2010; IUCN, 2011). Recently, the Western subspecies (Diceros bicornislongipes) was declared to be extinct, leaving only three subspecies on the continent (IUCN, 2011). With the escalation of poaching, understanding the needs of this elusive species is critical.

The majority of in situ research and management efforts are focused on recreating suitable habitat that will allow black rhino populations to increase (e.g. Birkett, 2002; Reid et al., 2007; Linklater and Swaisgood, 2008; Morgan et al., 2009). However, the impact of environmental conditions on population growth need to be further investigated with minimal disturbance. One method of studying these impacts on individual is to monitor biological factors including reproductive and stress physiology. Recently, hormonal analysis using samples collected by non-invasive methods, such as faecal or urine collection, have been developed. Non-invasive hormonal monitoring is advantageous because 1) hormones are concentrated versus continuous fluctuations found in the blood stream; 2) feces are easy to obtain without disturbing the subject through capture and handling and often provide large quantities of sample; 3) frequent collection can provide a longitudinal profile and better interpretation of the hormonal patterns; 4) hormone metabolites in faecal and urine samples are from several hours or days prior to collection and provide further comprehensive assessment (Monfort, 2003).

Few endocrine studies have been conducted on wild black rhino, including a field pregnancy test (MacDonald et al., 2008) and evaluation of estrous cyclicity and the influence of season on reproduction (Garnier et al., 2002). Additionally, faecal hormone concentrations and scent-marks have been evaluated relative to distance traveled post-release in translocated black rhino (Linklater et al. 2006). Extensive endocrine studies have been carried out in zoos (Brown et al., 2001; Carlsteadand Brown, 2005; Carlstead et al., 1999; Wasser et al., 2000). Because zoo-housed individuals are managed under different environmental and dietary conditions than wild black rhinos, we cannot assume that hormonal patterns are similar between wild and captive populations. Therefore, our goal is to establish a health monitoring program that will investigate the relationship among hormonal activity and ecological factors of a population of south-western black rhino subspecies (Dicerosbicornisbi cornis) found in two sections (Addo and Nyathi) of Addo Elephant National Park (AENP) in Addo, South Africa. Our specific objectives are to investigate the impact of resource availability (competition with elephants), predation pressures (lions and hyenas) and eco-tourism on the rhinos' health and reproduction using non-invasive field methods. Our hypotheses are that: 1) high densities of elephants, predators and tourists are associated with a suppression of gonadal (reproductive) activity in black rhino; and 2) adrenocortical activity is positively associated with high anthropogenic activity and negatively affects reproduction in the black rhino.

METHOD

Study Area

The AENP is located in the Eastern Cape of South Africa and was originally founded in 1931 to protect the remaining 11 elephants in the area (Whitehouse and Hall, 2000). In 1995, indigenous black rhinos of this ecotype (D. b. bicornis) were reintroduced into the AENP and the eastern black rhino subspecies (D. b. michaeli) were removed. Our study focused on two sections, Addo's Main Camp and Nyathi, which have varying biotic and abiotic characteristics (Table 1).

Table 1. The varying abiotic and biotic factors of our study area, which includes two sections in AENP (Addo and Nyathi) that are separated by a highway and fence.

Factors	Addo	Nyathi
Sex ratio	Female-biased	Male-biased
Elephant density	High (~300)	Moderate (~100)
Predators	Present	Absent
Vegetation	Limited	Abundant
Tourism	High	Low
Size of section	11,500 ha	14,000 ha

Rhino Population

There were 44 black rhinos managed in the two sections of AENP, Addo: n = 18 (9 females, 8 males, 1 unsexed) and Nyathi: n = 26 (11 females, 13 males, 2 unsexed). Each rhino is immobilized at approximately 2 to 4 years of age and given a specific pattern of ear notches that can be used to identify individuals. Prior to notching, rhinos can be positively identified by other anatomical features, such as their size, horn and body scars, and by association with their mother.

Camera Traps

The camera traps were placed in areas based on black rhino sightings by AENP staff and at active latrines called middens, which are areas where black rhinos defecate and then scrape the feces with their hind legs to spread odors advertising their presence (Hutchins and Kreger, 2006). A high-quality digital photo was quietly taken when the camera was activated through a passive infrared motion detector. Each morning that fresh feces were found in view of a camera, a sample was collected and stored in a cooler. The images stored on the camera were checked to identify the individual that defecated and assess body condition; time of defecation also was determined from the photo.

Faecal Hormone Monitoring

Faecal samples were monitored daily by two methods: camera traps and direct observation of individuals defecating. Faecal hormones were extracted from feces using a field technique (Santymireand Armstrong, 2010). Faecal progestin metabolite concentrations analysis was conducted in the field to test for pregnancy (Freeman et al.,2010; MacDonald et al., 2008). However, these results were verified at Lincoln Park Zoo's (LPZ's) endocrinology laboratory along with additional analyses for faecal androgen and corticosterone (for stress analysis) metabolite concentrations. An USDA importing permit (# 107647) was obtained.

Data Analysis

Data analysis was done using Systat 12 and Sigma Plot v.11 (SPSS, Inc.). A Kolmogorov-Smirnov test was used for normality assumption testing and the Levene median test for equal variance assumption testing. Non-parametric tests were used when data were not normal. Analysis of Variance (ANOVA) was used to compare among individuals, seasons and reproductive state. For all analyses, $P < 0.05$ was considered significant.

RESULTS

Over 250 faecal samples from known individuals(21 males; 22 females)were collected for over 3 years. Pregnancy was accurately diagnosed in 100% (n = 7 females) of females. Progestin metabolite values were higher (Mann-Whitney: $T_{12,33} = 461.0$, $P < 0.001$) in pregnant (533.4 ± 106.0 ng/g feces) versus non-pregnant (78.6 ± 8.5 ng/g feces) females. The inter-calf interval was 33.5 ± 6.1 months (n=7) in Addo versus 25.5 ± 1.6 months (n=12) in Nyathi. Faecal progestin metabolites were lowest (Kruskal-Wallis: $H_3 = 11.001$, $P = 0.012$) in the winter (103.8 ± 31.4 ng/g) compared to fall (166.9 ± 34.6 ng/g), but both were similar to spring (149.8 ± 47.3 ng/g) and summer (177.4 ± 71.8 ng/g). For males, faecal androgen metaboliteswerehigher (Kruskal-Wallis: $H_3 = 12.543$, $P = 0.006$) in summer (110.5 ± 10.3 ng/g) and spring (139.6 ± 16.1 ng/g) months and lowest in the winter(71.8 ± 7.0 ng/g), but similar ($P>0.05$) to fall

(108.9 ± 10.1 ng/g). Faecal glucocorticoid metabolites were similar ($P>0.05$) between sexes and age groups; however, Addo (160.5 ± 14.8 ng/g) had higher (Mann-Whitney: $T_{58,164} = 8125.0$, $P < 0.001$) concentrations compared to Nyathi (112.9 ± 8.6 ng/g). In Addo, concentrations of faecal glucocorticoid metabolites were lower (Kruskal-Wallis: $H_3 = 13.459$, $P = 0.004$) in the winter (94.1 ± 17.5 ng/g) than summer (232.1 ± 30.2 ng/g), but fall (111.5 ± 13.0 ng/g) and spring (145.9 ± 22.6 ng/g) were similar ($P>0.05$) to both seasons. Similarly, faecal glucocorticoid metabolites in Nyathiwere higher (Kruskal-Wallis: $H_3 = 23.406$, $P < 0.001$) in fall (109.3 ± 9.2 ng/g) and spring (186.3 ± 26.4 ng/g) than winter (59.3 ± 7.5 ng/g), but summer (96.7 ± 14.4 ng/g) was similar ($P>0.05$) to the other seasons.

DISCUSSION

We overcame the challenges of studying this elusive species by using camera traps on middens to identify the individual faecal sample. Using non-invasive sampling allows for the investigation of environmental pressures on the black rhino with minimal disturbance. Additionally, by processing the samples in the field (Santymire and Armstrong, 2010) we could analyze the sample immediately for pregnancy (Freeman et al., 2010) and have a safe and reliable method for shipping the samples back to the laboratory for analysis.

Our results are the first steps in understanding how varying environmental pressures can impact the success of the wild black rhino in AENP. Overall, we observed some effects of season on reproductive hormones with lower faecal androgen (in males) and progestin (in female) metabolites in the winter. In future analyses we will compare wet versus dry seasons, as precipitation rates may be more of the driving factor of reproduction. We also observed a year longer calving interval in Addo compared to the Nyathi section indicating that there may be factors that were impacting reproduction in the Addo section black rhinos. The recent literature indicates that it is important to monitor how reproduction is linked to adrenocortical activity (Linklater et al., 2010) in black rhinos. Some of the possible pressures in the Addo section include more elephants, presence of predators and the majority of tourist vehicles on roads than the Nyathi section. Black rhinos select their habitat based on a variety of factors, including distance to water, roads and fences, not simply on the quality of available browse (Morgan et al., 2009). Additionally, population models predict that competition with other browsers (e.g. elephants) and low precipitation rates could negatively impact reproductive success of black rhinos (Birkett, 2002). Decreases in food, water and shelter availability along with increased human disturbance results in larger home ranges and lower black rhino reproductive success (Reid et al., 2007). Here we determined that the Addo black rhinos had higher faecal glucocorticoid metabolite concentrations than Nyathi, which reinforces that one or all of these factors are impacting the population. Similarly, differences in competition for food, water and shelter between the AENP sections could affect hormonal activity and ultimately lead to differences in reproductive success and health among individuals.

Conservation implications

With validated, non-invasive monitoring methods, our long-term goal is to establish a multi-year, health monitoring program to investigate the relationship among black rhino hormonal activity, parasitic infection rates and varying abundance of mega-herbivores, predators and humans. Results will be used to facilitate management decisions for black rhino conservation. Investigating the impact of the biotic and abiotic differences between Addo and Nyathi will lead to a greater understanding of black rhino ecology and reproduction. This knowledge will be able to enhance SAN Parks commitment to conservation efforts of the critically endangered black rhino by improving decision making based upon science and leading to the reproductive success of black rhinoceros within other national parks where they occur.

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SPECIES, ABUNDANCE AND CONSERVATION STATUS OF FROGS COLLECTED FOR DISSECTION IN TANZANIAN SECONDARY SCHOOLS: CASE OF SELECTED SCHOOLS IN DODOMA AND DAR ES SALAAM REGIONS

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ABSTRACT
Frogs and toads are declining at an alarming rate throughout the world. However, in Tanzania frogs are freely collected from the wild for dissection in high school biology exercises and practical examinations. This study aimed at assessing species abundance and conservation status of frogs collected by six high schools from Dodoma and Dar es Salaam Regions in order to establish whether such collection has or may have an adverse impact on the long term survival of frogs in Tanzania. Frog specimens preserved for dissection purposes in laboratories of the six selected schools were identified to species level, counted, measured and the conservation status of each species as per the IUCN Red List was determined. Moreover, field surveys were conducted at various sites to determine and compare species richness, abundance and diversity of frogs between wetlands where frogs were collected for dissection and in areas where there was no collection activity. In addition, questionnaires were distributed to six biology teachers and 190 students from the six schools to seek their opinions and concerns about frog dissection exercises. It was found that five frog species from four different families were collected for dissections in the schools visited. All five frog species were classified as of Least Concern in the IUCN Red List. There was a marked regional variation in the most frequently collected frog species. Shannon Weiner index of diversity of frogs in sites where they were collected for dissection was lower than in sites where there was no collection, but the difference was not significant. The Ministry of Education and Vocational Training is advised to review the use of frog dissection in biology teaching in high schools to ensure that the declining amphibian populations in the country are not overexploited for specimen used in dissections. More studies are required to explore the scenario in other regions and establish a full list of frog species collected for dissection in Tanzania.

Key words: Amphibian decline, frog dissection, IUCN Red List, Dar es Salaam, Tanzania

INTRODUCTION

Dissection is considered a standard method of teaching comparative internal anatomy and physiology of different animals to students in secondary schools, colleges and universities throughout the world (Balcombe, 2000; Van der Valk, 2006). During the dissection exercises, students learn the skills of cutting and opening an animal without disturbing its internal organs, pinning the different organs, identifying the internal parts and drawing them (Morrison, 1992). Unfortunately, the animals dissected are killed during or before the dissection process.

The curriculum of Tanzanian secondary schools requires students studying advanced level biology to perform dissection of animals in the laboratory and in practical examinations. The animals used mostly are frogs/toads, rats/mice and cockroaches (MoEVT, 2009). With exception of rats/mice which are commonly raised in laboratories, the other animals are collected from their natural habitats, usually by students themselves.

Student enrollment in Tanzanian secondary schools is tremendously expanding following success of the Secondary Education Development Program (SEDP) launched in 2004. In 2003, about 350,000 students were enrolled in form 1- 6, but the number increased to 675,672 in 2006 and in 2010 it grew to 1,638,699 (MoEVT, 2010). The government is currently implementing phase two of SEDP which entails expansion of high schools in order to enroll an increasing number of students graduating from ordinary level secondary schools. Statistics shows that about 25% of high school students study biology and thus perform animal dissections (MoEVT, 2010).

Despite the fact that there are increasing concerns from biologists that amphibians are declining at an alarming rate throughout the world (Blaustein and Wake, 1990; Houlahan et al., 2000; Afrol News, 2004; Stuart, et al., 2004), dissection of the frog has remained an important exercise in high school biology in Tanzania. Since the introduction of frog dissection exercises in the Tanzanian secondary school curriculum during the pre-independence years, no study has been conducted to assess the species and conservation status of the frogs dissected. The relevance of the frog dissection exercises in the midst of the current amphibian decline crisis and increasing student enrolment has also not been carefully considered. According to the IUCN Red List, 52 of the 194 amphibian species that occur in Tanzania are threatened with extinction. One species, the Kihansi spray toad Nectophrynoides asperginis, is extinct in the wild (EW), 5 species are critically endangered (CR), 24 are endangered (EN), 20 are vulnerable (VU), and 2 are near threatened (NT) (IUCN, 2010; Amphibiaweb, 2011). If we ignore the data deficient (DD) and unevaluated (UN) species (n = 30) whose conservation status is still unknown with certainty, we can conclude that over 31% of the amphibian species in Tanzania are threatened. Also, the population trend of over 40% of all the frog species that occur in Tanzania is reported to be declining (IUCN, 2010).

The current study identified the species and conservation status of frogs collected for dissections in six selected schools in Dodoma and Dar es Salaam regions and investigated the impacts of the collections on species diversity and abundance of frogs in sites where collections were conducted. Attitudes, concerns and suggestions of high school biology teachers and students about frog dissections were also assessed.

MATERIALS AND METHODS

Study area

The study was conducted in Dodoma and Dar es Salaam Regions and it focused on high schools that teach advanced level biology. High schools with the following subject combinations were focused: PCB, CBA, CBG and CBN; where P stands for Physics, C for Chemistry, B for Biology, A for Agricultural Science, G for Geography, and N for Nutrition. Schools with these subject combinations were selected for study because frog dissections are only performed by high school biology students. The schools from Dodoma Region that participated in the study were Bihawana Secondary School, Hijra Seminary and Dodoma Secondary School and those from Dar es Salaam were Mbezi High School, Azania Secondary School and Jangwani Secondary School. Bihawana and Azania are boys' schools while Jangwani is a girls' school. The rest are co-educational.

Dodoma Region was selected because its semi-arid climatic condition which generally does not favor amphibians was assumed to present a challenge for students in the region in obtaining frog specimens. Also, owing to the aridity of the region, over-collection of frogs for dissection over time can be devastating to the frog populations because remaining individuals may not reproduce fast enough to counterbalance the effect of over-collection. Furthermore, Dodoma as one of the regions in Tanzania's central zone was focused because a herpetological survey conducted in Africa in 2004 cited central regions of Tanzania as areas where tens of amphibians are about to disappear (Afrol News, 2004). Dar es Salaam was selected for study because it is a large city where most amphibian breeding sites have been greatly destroyed by settlements and pollution and therefore students in the city could be getting problems in obtaining frog specimens. Dar es Salaam was also selected for comparison with Dodoma because the climatic conditions of the two regions differ significantly.

Data collection

Data were collected from January to May 2011 through assessment of laboratory specimens, questionnaires and field surveys. Frog specimens preserved for dissection in laboratories of six selected schools were identified, counted and measurements of body parameters (mass and snout-vent length) of some specimens of each species were taken. Conservation status as per IUCN Red List of each frog species observed was also determined. In addition, questionnaires with both open and closed-ended questions were distributed to 190 students and six biology teachers in the schools visited to seek their attitudes, concerns and suggestions about frog dissections. Also, field surveys were conducted using time-constrained Visual Encounter Survey (VES) method (Heyer et al., 1994; Sutherland, 1996; Dodd, 2009) in wetlands identified by the students and teachers as the main sites for collection of the frog specimens. The VES method was also employed to survey other adjacent wetlands where there was no record of frog collection. Species richness, abundance and Shannon Weiner diversity index (H') of frogs in sites where frogs were collected for dissections was determined and compared with sites where there were no collections.

Time-constrained VES method was selected because it is a quick and reliable method for assessing species richness and relative abundance of frogs (Heyer et al., 1994; Sutherland, 1996; Dodd, 2009). The technique is similar in principle to the method used by students when collecting frogs for dissection; the frogs are actively searched for and captured. Each study site was searched with the help of head-torches for 30 minutes, usually from 19.00 to 23.00 hours. The surveys were conducted during the night because frogs are most active at night during the wet season and thus they are easier to detect (Sutherland, 1996; Dodd, 2009). All the frogs observed or heard within the search area were identified and recorded and the size of the area searched was measured after the search time had finished. Except for frogs that were difficult to identify in the field thus necessitating collection of some voucher specimens, all other species were identified on site, photographed and released. Identification of the frog species was performed with guidebooks by Channing and Howell (2006), and Carruthers and Du Preez (2011). Also, photographs of all the frogs observed were sent to skilled herpetologists in Dar es Salaam for confirmation of their identities.

Data analysis

Number, species and status in the IUCN Red List of all the frogs observed in the laboratories and in the field were determined. Density and encounter rate of frogs of different species seen or heard in the field were calculated. A two sample t-test (α = 0.05) was employed to find out whether abundance of frogs at sites where frogs were collected for dissection differed significantly from adjacent sites where there were no collection. The t-test was performed with GraphPadInstart statistical programme (Instart, 2001). Shannon Weiner diversity index (H') of frogs at the collection sites and at the sites where there were no collection was also calculated. The Hutcheson's t-test for difference between two diversity indices (Zar, 1999) was employed to test whether the diversity indices of frogs at the two sites was significantly different. The data on attitudes and opinions of students and teachers about frog dissections were analyzed with the Statistical Package for Social Sciences (SPSS) version 16 for windows (SPSS, 2007). Descriptive statistics were applied to analyze mean sizes of frogs and are herein reported as mean ± standard deviation.

RESULTS

Species of frogs used for dissections and their conservation status

A total of 128 preserved frog specimens of five different species in four families were found in laboratories of all the schools visited (Table 1). There were marked variations between schools and regions in terms of species and relative abundance of the preserved frogs but all species were classified as of Least Concern (LC) in the IUCN Red List. The population trend of all the frog species observed is reported to be stable except that of the guttural toad Amietophrynus gutturalis which is claimed to be on the increase (IUCN, 2010).

Table 1: Species, abundance and conservation status of frogs used for dissection sessions

FROG SPECIES				NUMBER OF FROGS FOUND IN THE VISITED LABORATORIES						
Common Name	Scientific Name	Family	Status in 2010 IUCN Red List	DODOMA			DAR ES SALAAM			TOTAL
				Bihawana	Hijra	Dodoma	Mbezi	Azania	Jangwani	
Guttural toad	*Amietophrynus gutturalis*	Bufonidae	Least concern	0	0	1	28	32	0	61
Muller's platanna	*Xenopus muelleri*	Pipidae	Least concern	29	11	1	0	0	0	41
Anchieta's ridged frog	*Ptychadena anchietae*	Ranidae	Least concern	20	0	0	0	0	0	20
Mascarene ridged frog	*Ptychadena mascareniensis*	Ranidae	Least concern	0	3	0	0	0	0	3
Edible bullfrog	*Pyxicephalus edulis*	Pyxicephalidae	Least concern	0	0	0	0	3	0	3
TOTAL	-	-	-	49	14	2	28	35	0	128

Attitudes of students and teachers about frog dissections

Six high school biology teachers and 190 students from the six selected schools were interviewed. Of all the students interviewed, 46.8% (n = 190) were in form five and 53.2% (n = 190) were in form six. The age of the students ranged from 17 to 27 years. The teachers interviewed included four males and two females with a range of 2-26 years of experience in teaching high school biology.

The results suggest that all the teachers interviewed (n = 6) and the majority of students (98.4%, n = 190) liked the animal dissection exercises. Of all the students interviewed, 75.3% admitted that they had already dissected at least one frog, rat or cockroach. When asked which of these animals they preferred most to dissect, 52.1% claimed to prefer the frog, 37.4% claimed to prefer the rat, and 9.5% suggested the cockroach. A minority of them (1.1%) either mentioned a different animal or did not respond to the question.

Students who preferred the frog for dissection (n = 97) reported that they preferred the animal because frogs were easy to dissect, display and the internal organs could easily be sketched (58.8%; n = 97). Other reasons provided were that frogs were easy to find (21.7%; n = 97); frogs were large so their internal organs could be seen clearly (9.3%; n = 97); frogs have many internal systems to learn so it offered them a challenge (3.1%; n = 97); it was easy to make a comparison between the frog and human being during dissection (2.1%; n = 97); and 2.1% (n = 97) said they liked the frog because it was the only animal they had ever dissected. However, 3.1% (n = 97) of the students who said they preferred the frog did not provide any reason for their preference. The majority of the students, 90.5% (n = 190) were optimistic that the knowledge and skills they obtained from frog dissections would be useful in their future careers. However, few students (5.3%; n = 190) said the skills they acquired from frog dissections would not be of use in their future careers and 4.2% (n = 190) were unsure whether the dissection skills would be of use in their future careers.

Species, size and availability of frogs preferred for dissection

Students were asked whether they preferred certain frog species for dissection or they used frog species based on availability. The majority of respondents (71.1%; n = 190) said they preferred some species but 27.4% (n = 190) said they used any species they could find. However, all respondents were unable to identify frogs to species level hence they were not further questioned to determine which species they preferred. However, most students (95.7%; n = 190) claimed to prefer medium-sized to very large frogs. Analysis of sizes of frogs observed in the visited laboratories showed that the average snout-vent length of frogs collected was 56.8 ± 10.6 mm (n = 44). When asked how easily could the frogs be obtained during the rainy season, 92.6%; (n =190) of the respondents reported that it was very easy to moderately easy. However, 91.6%

(n = 190) of the respondents admitted that the availability of the frogs during the dry season becomes difficult. Due to scarcity and seasonality in the availability of frogs, five of the six schools visited employed a strategy of collecting many frogs during the rainy season when frogs were readily available and preserved them in the laboratory for later use. Also, two schools in Dodoma Region (Bihawana and Dodoma Secondary Schools) had started to raise frogs for dissections.

Number of frogs dissected by students

The six biology teachers interviewed admitted that the biology syllabus required them to teach dissection of the frog and those students usually performed three to four formal frog dissections during the two years of high school education. This implies that, provided there is no sharing of specimens, each high school biology student dissects three to four frogs in formal laboratory practical during the two years of study. However, this number does not take into account other specimens that most students dissect on their own time outside the formal laboratory exercises. In order to take into account the number of frogs dissected outside the formal laboratory practical sessions, students were asked to list the number of frogs they had dissected since they started high school education. Analysis of responses from form six students (n = 48) during the last week of their study showed that, on average, a high school biology student dissected 5.7 ± 4.9 frogs during the two years of study. The actual number of frogs dissected per student varied from 1 to 25.

Suggestions of students for future conservation of frogs

Students were briefed about the amphibians decline crisis and then asked for suggestions to ensure that collection of frogs for dissection will not contribute to the future disappearance of frogs in Tanzania. The majority of the respondents (80.5%; n = 190) suggested that high schools that teach biology should establish ponds for raising the frogs needed for dissection instead of collecting them from the wild, while 3.2% (n = 190) suggested that the government should abandon the frog dissection exercises altogether. Another 3.2% (n = 190) suggested that the environment should be conserved so that frogs could continue to survive. Other respondents recommended that people should be educated about the frog decline crisis (2.7%; n = 190), and the government should regulate capturing of frogs for dissections (1.6%; n = 190). However, 1.1% (n = 190) of the respondents did not believe that frogs could disappear because they had an opinion that frogs reproduced very quickly and produced so many offspring at one time.

Field surveys

Field surveys were conducted at night during the short rains from January to May, 2011. We spent 660 minutes (= 11 hours) actively searching 22 wetland sites (ponds, puddles and flood plains) covering 6007m2 in Dodoma and Dar es Salaam Regions.

Distribution of the survey time was such that 270 minutes (= 4.5 hours) were spent in surveying wetlands in Dar es Salaam and 360 minutes (= 6.5 hours) were spent in surveying wetlands in Dodoma. All the frogs observed or heard within the survey area were identified to species level, counted and body parameters (mass and snout-vent length) of some representative individuals of each species were taken.

During the field surveys, 378 frogs of 14 different species from nine families were recorded in the two regions (Table 2). The status in the IUCN Red List of all the frog species recorded was of Least Concern and their population trend was reported to be stable except the dwarf leaf-folding frog Afrixalus brachycnemis whose population trend was reported to be on the decline, A. gutturalis whose population trend was reported to be on the increase, and the marbled snout-burrower Hemisus marmoratus whose population trend was unknown (IUCN, 2010). Dar es Salaam was richer than Dodoma both in species and abundance of frogs but the difference was not significant ($t = 1.069$, $df = 20$, $p = 0.2976$). Dar es Salaam had a record of 12 different frog species while only 10 species were recorded in Dodoma. However, about half of the species recorded (57.1%; n = 14) co-occurred in the two regions (Table 2).

Table 2: Species and abundance of frogs recorded during the field surveys in wetlands located in Dodoma and Dar es Salaam, January – May 2011.

Frog Species	Family	Number of frogs per region		
		Dodoma	Dar es Salaam	Total
Afrixallus brachycnemis	Hyperoliidae	0	24	24
Amietophrynus gutturalis	Bufonidae	2	82	84
Arthroleptis sternodactylus	Arthroleptidae	0	6	6
Chiromantis xerampelina	Racophoridae	30	2	32
Hemisus marmoratus	Hemisotidae	17	4	21
Hildebrandtia ornate	Ranidae	2	0	2
Kassina senegalensis	Hyperoliidae	0	8	8
Leptopelis bocagii	Hyperoliidae	1	0	1
Phrynobatrachus mababiensis	Ranidae	3	8	11
Phrynomantis bifasciatus	Microhylidae	3	31	34
Ptychdena anchietae	Ranidae	70	4	74
Ptychdena mascareniensis	Ranidae	30	5	35
Pyxicephalus edulis	Pyxicephalidae	0	11	11
Xenopus muelleri	Pipidae	29	6	35
Total	-	187	191	378

Impact of frog collection for dissection on abundance and diversity of frogs

A total of 16 wetland sites in Dodoma covering 4,246 m2 were surveyed of which seven were located in areas where schools collected frogs for dissection and the rest were located in areas with no record of frog collection. While nine different frog species were recorded in the sites with no record of frog collection, sites where frogs were collected recorded only seven frog species. However, despite the lower species richness, sites where frogs were collected had a higher abundance of frogs than sites where there was no frog collection, but the difference in frog abundance between the sites was not significant (Figure 1, $t = 1.245$, $df = 14$, $p = 0.2337$). Hutcheson's t-test for difference between two diversity indices (Zar, 1999) revealed that the Shannon Weiner diversity index of frogs at collection sites (H' = 0.5743) did not differ significantly from that of sites where there was no collection (H' = 0.7396).

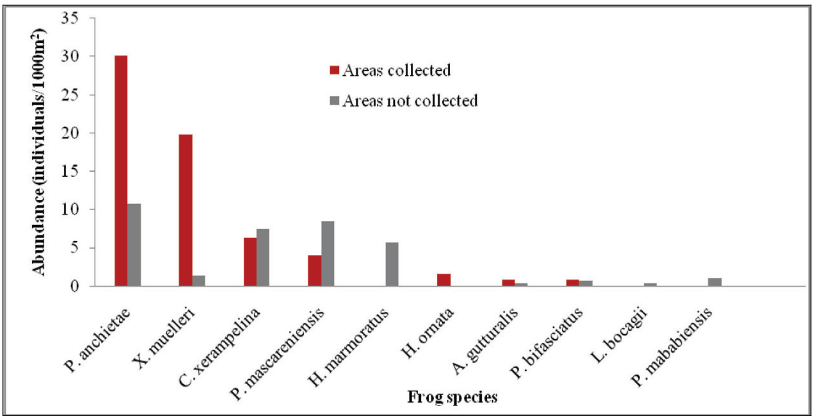

Figure 1: Comparison of species richness and relative abundance of frogs at sites routinely used by schools for frog collection and sites with no frog collection in Dodoma Region, January – May 2011

DISCUSSION

Overview

Frogs are mostly cryptic and secretive in their habits thus they pose a major problem to anyone who seeks to estimate their numbers accurately (Sutherland, 1996). However, they become most active and thus easily censured at night especially during the rainy season when they come out of hiding to breed. This study was conducted at night during the rainy season which is the ideal time for frog census (Heyer et al., 1994; Sutherland, 1996; Dodd, 2009). However, it cannot be guaranteed that all the frogs in the surveyed sites were recorded because each site was only surveyed once, so some species might have been missed. Also, ground cover at the sites varied broadly which might have affected the visibility of some frogs. However, the findings still provide good insights into the impacts of frog collections for dissections.

Species of frogs used in dissections and their conservation status

The frog species used for dissections both in Dodoma and Dar es Salaam Regions were the relatively large frogs (average snout-vent length = 56.8 ± 10.6 mm) found in the respective regions. Possibly, the students preferred large frogs for dissections because their internal organs and systems could be seen more clearly with naked eyes than in small frogs. Some small frogs like the puddle frog P. mababiensis and the dwarf leaf-folding frog A. brachycnemis were common in the sites surveyed in Dar es Salaam but none were represented in the school labs.

Although the frog species that are mostly collected for dissection in Dodoma and Dar es Salaam schools are of Least Concern and their population trend is stable or increasing(IUCN, 2010), some of them might be Endangered at local levels. This is so because Tanzania does not have a national Red List and thus the local status of many frog species is unknown. Example, guttural toads are very scarce in the drier areas of Dodoma but are still collected for dissections.

The marked difference in species and relative abundance of preserved frogs at schools in Dodoma and Dar es Salaam region was mainly caused by differences in distribution and abundance of the species between the two regions. For example, the observation that P. edulis is collected in Dar es Salaam but not in Dodoma is not surprising because the species is not found in Dodoma (Channing and Howell, 2006). The predominance of P. anchietae in laboratory specimens in Dodoma schools is due to its high abundance in the region. The predominance of A. gutturalis in Dar es Salaam is due to wet climate of the region and its adaptability to the anthropogenicaly modified environment. Its low abundance in Dodoma may be due to scarcity of water because the frog occurs in dry areas only where there are permanent sources of water (Channing and Howell, 2006).

Number of frogs collected for dissections

The majority of students interviewed preferred to dissect frogs rather than rats and cockroaches, and on average a student dissected 5.7 ± 4.9 frogs during the two years of high school education. This suggests that it is important we revisit frog dissection exercises for the future conservation of frogs because student numbers are increasing with corresponding risk of over-collecting frogs from the already declining wild populations. if the dissection exercises are left to continue in the current setting. The suggestion provided by majority of students that schools should establish ponds to raise the frogs they need for dissections sounds promising but it is unlikely to stop the collection of frogs from the wild. The two schools in Dodoma that had established their own frog ponds still obtained most of their specimens from the wild because the ponds were not productive enough to meet demand. Also, most schools could not feed the frogs adequately and were not experts on the ecology of the frog species.

Impact of dissections on abundance and diversity of frogs

The observation that abundance and diversity of frogs in sites where frogs were collected for dissection was not significantly lower than in sites where there was no collection signifies that the collection of frogs for dissection has not yet caused significant adverse impact on the frog populations. However, as student enrolment in high schools continues to expand, the collection of more frogs might result in significant adverse impacts. The high abundance of preferred frog species such as P. anchietae and X. muelleri at some of the collection sites might be due to selection by frog collectors of sites that were abundant in those species or the frog species were producing more offspring as a response to the high collection intensity. The later possibility needs more research to conclude the assumption.

Attitudes of students and teachers about frog dissections

Attitudes play an important role in shaping human behavior (Kellert and Westervelt, 1983). The attitudes of students and teachers towards or against animal dissection not only affect teaching and learning but also may have an impact on populations of the animals dissected. Students who are highly motivated to dissect certain animals may over-collect the animals thus devastating the populations if the collection is done beyond sustainable limits. Over 98% (n = 190) of interviewed students and 100% (n = 6) of the teachers interviewed in the present study had positive attitudes towards animal dissections and more than half of the students (52.1%, n = 190) preferred frogs to rats and cockroaches. This study found that relatively more students and teachers had positive attitudes towards animal dissection than similar studies (eg. King et al., 2004; De Villiers and Sommerville, 2005) conducted in other parts of the world.

The higher percentage of students and teachers expressing positive attitudes towards animal dissection observed in this study is attributed to several possible reasons. The Tanzanian high school biology curriculum places much emphasis on dissection exercises such that form six national examinations always include a question on animal dissection and that question is compulsory is compulsory for every candidate. Many teachers and students lack awareness and access to alternative methods to dissection like computer-based dissection tools. Also, most students and teachers are unaware of contemporary biodiversity issues like the amphibian decline crisis, and there is generally low level of animal rights or animal welfare activism in the country. Conservation biologists and animal rights activists in the United States of America play a major role in sensitizing the public about threats facing frogs, thus influencing attitudes of teachers and students about frog dissections (Savethefrogs, 2011).

CONCLUSION AND RECOMMENDATIONS

A large number of frogs are collected from the wild for dissection by high school biology students in Tanzania. The collection of frogs for dissection is usually done during the critical reproductive period when the frogs congregate in wetlands to breed. Because frogs are declining and student enrolment in secondary schools is rapidly expanding, this study recommends for review of animal dissection in high school biology in order to reduce or do away with frog dissections except where it is absolutely necessary (e.g., in medical and veterinary training). We recommend the introduction of alternatives to animal dissection like three dimensional anatomical models, wall charts, detailed text books with good pictures of the structures of dissected animals and computerized interactive Compact Disc Read Only Memories (CD-ROMs) simulating dissection of the frog and other animals to complement or replace real animal dissections. Although some authors have criticized the alternative methods in favor of real dissections, most studies conducted to compare performance of students that used real animal dissections and those that used the alternative methods found dissection alternatives produced just as good or better results. This suggests that alternatives to real animal dissection are effective and pedagogically sound hence they can be adopted without compromising teaching and learning outcomes.

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IS KATAVI IN TROUBLE?

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ABSTRACT

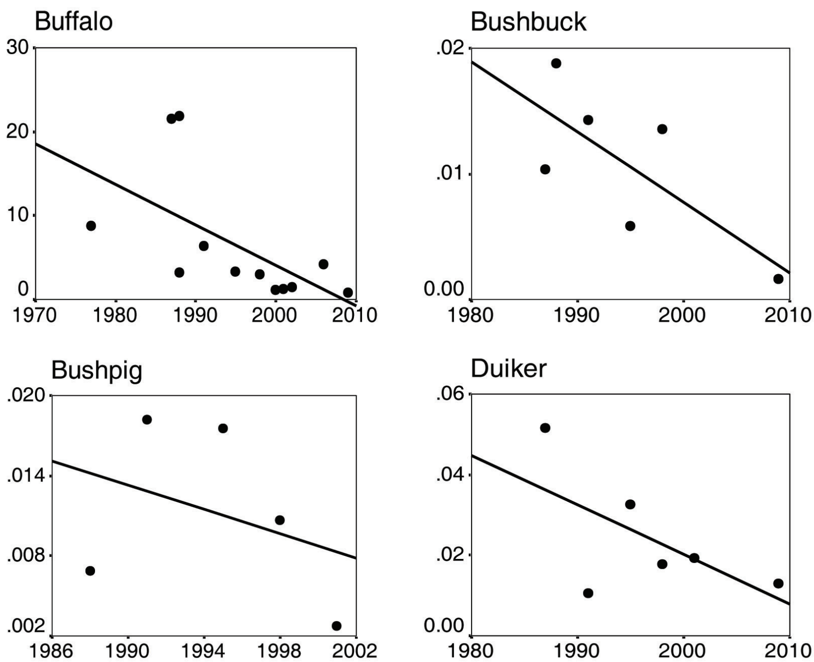
Long term aerial censuses conducted by TAWIRI show that many large and medium-sized mammal populations in the Katavi-Rukwa ecosystem are declining. Two ideas have been proposed to explain these changes: (i) reduced water flow through Katavi National Park caused by local damming of the Katuma River for rice cultivation upstream of the Park, and (ii) poaching inside the Park. We used vehicle transect data, national park anti-poaching records, timing of dam emplacements, and rainfall records to examine the importance of these factors over time. Numbers of mammals counted per year was influenced both by poaching and by dams but this varied according to species. In particular, declines seen in elephant and lion population estimates were associated with poaching pressure. Hippopotamus population estimates showed an increase that have not been affected by damming. TANAPA and local politicians need to address both poaching pressure and water diversion urgently because both are adversely affecting Tanzania's third largest national park.

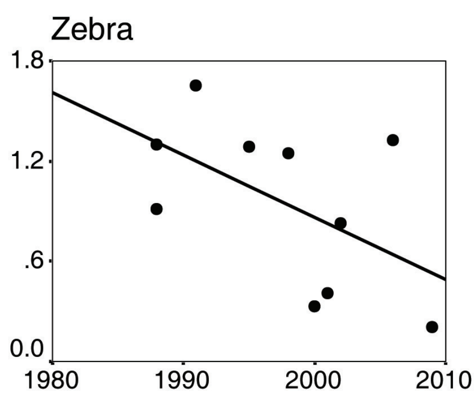
INTRODUCTION

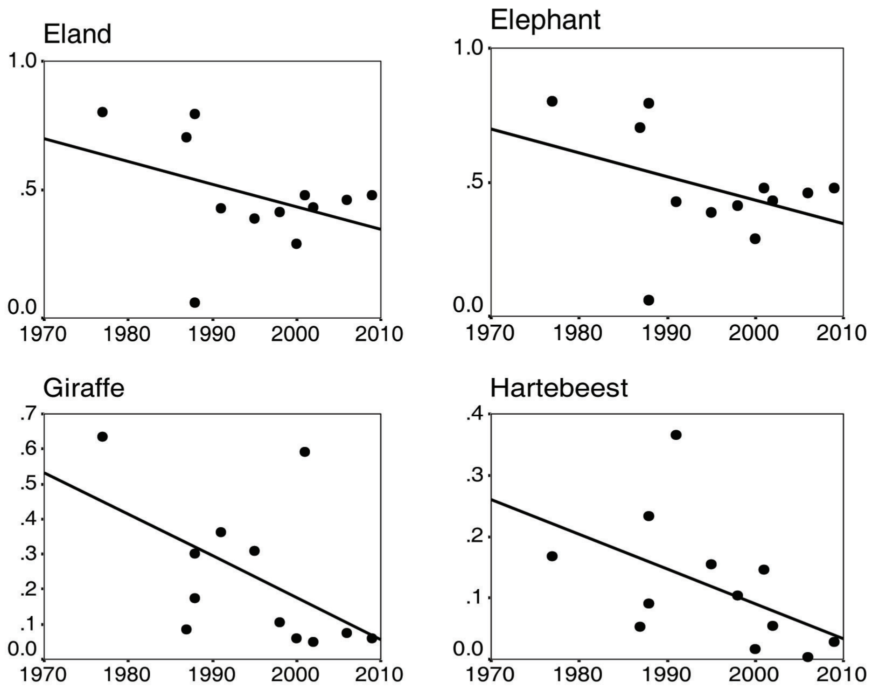
The Katavi-Rukwa ecosystem in western Tanzania is one of the country's largest remaining wildlife areas (approximately 12,000km2) but repeated aerial censuses of 16 large ungulate species carried out between 1977 and 2009 by TAWIRI show that many mammal populations are decreasing (Figure 1). Statistically significant declines have been witnessed in densities of buffalo (*Syncerus caffer*), eland (*Taurotragus oryx*), waterbuck (*Kobus ellipsiprymnus*), topi (*Damaliscus lunatus*), warthog (*Phacocherus africanus*), reedbuck (*Redunca arundinum*) and impala (*Aepyceros melampus*) and marginally significant declines in both giraffe (*Giraffa camelopardalis*) and hartebeest (Alcelaphus buselaphus). Furthermore, no statistically significant increases were witnessed in population densities of any species in the ecosystem.

Informally, it is recognized that at least two factors are threatening this ecosystem. Locally constructed dams to the north west of the park are thought to have reduced water flow through some of the major rivers and floodplains in the Park (Manase et al. 2011) and illegal hunting occurs inside both Katavi National Park and Rukwa Game

Reserve (Caro 2008; Martin et al. 2012). However the relative importance of these human-induced pressures is not well understood. Here we examine the effects of these disturbances using a time series of population estimates derived from vehicle transects. Our findings support these informal concerns about threats to wildlife in Katavi National Park, and we make recommendations as to how to conserve wildlife in the area.



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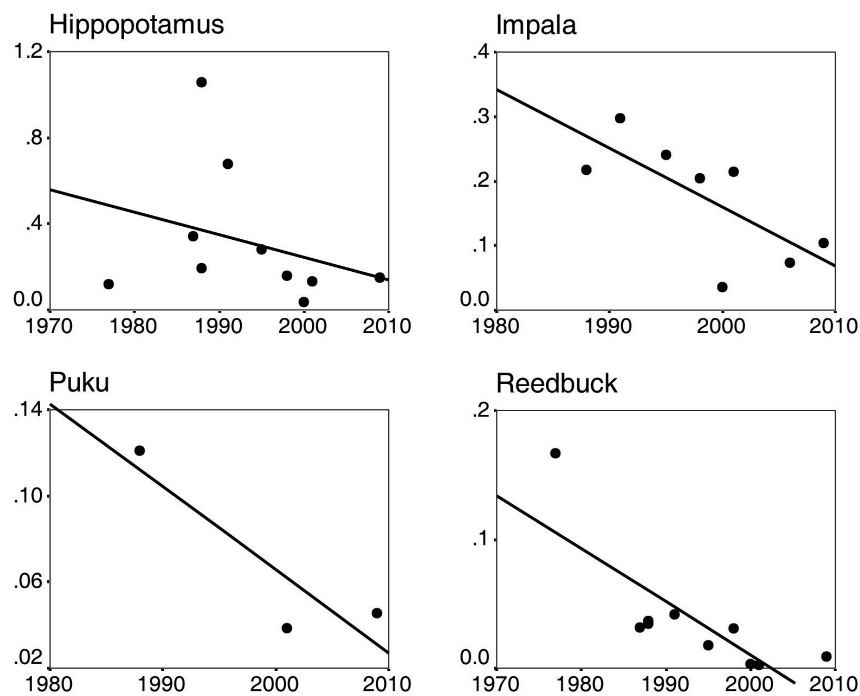
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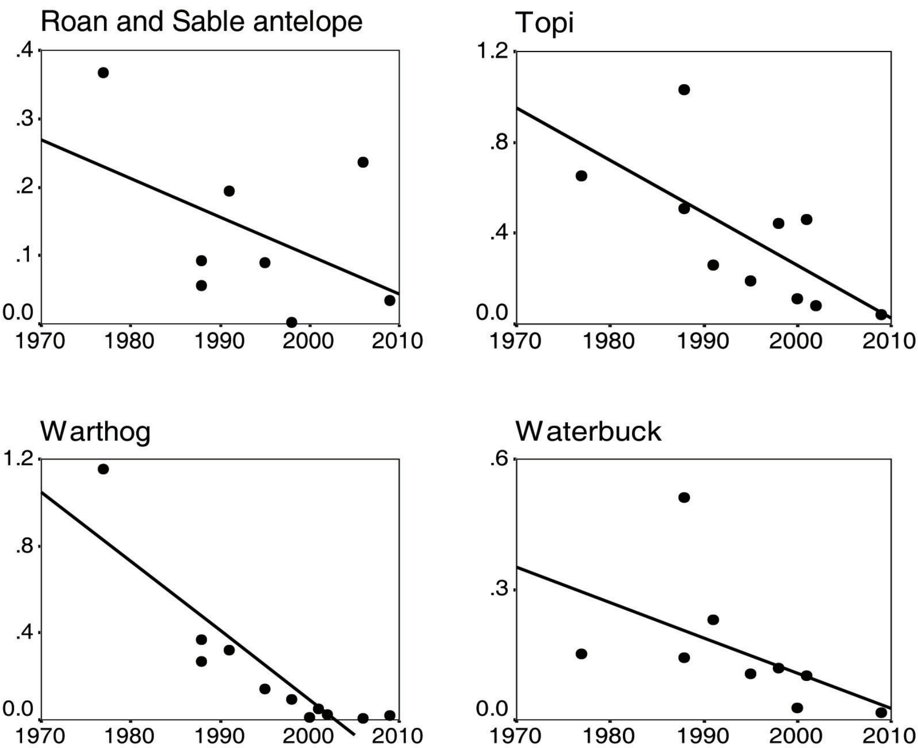

Figure 1. Densities taken from aerial surveys over the Katavi-Rukwa ecosystem conducted between 1997 and 2009. Panels show densities of large and medium-sized mammals (individuals per km2) plotted against year. Spearman rank correlation coefficients: elephant N = 12 surveys, rs = -0.203, NS; hippopotamus N = 10, rs = -0.383, NS; giraffe N = 12 rs = -0.571, P = 0.053; buffalo N = 12 years, rs = -0.750, P = 0.005; eland N = 10, rs = -0.632, P = 0.05; roan and sable antelope combined N = 8, rs = -0.455, NS; zebra N = 10, rs = -0.474, NS; waterbuck N = 9, rs = -0.862, P = 0.003; hartebeest N = 12, rs = -0.571, P = 0.053; topi N = 10, rs = -0.821, P = 0.004; bushpig N = 5, rs = -0.400, NS; warthog N = 11, rs = -0.911, P<0.001; puku N = 3 too few to test; reedbuck N = 10, rs = -0.839; P = 0.002; impala N = 8, rs = -0.714, P = 0.047; bushbuck N = 6, rs = -0.543, NS; duiker N = 6, rs = -0.371, NS. Regression lines are added simply for clarity.

METHODS

Study area

Katavi National Park (4471 km2) was formerly situated in Mpanda District, Rukwa Region but is now in Katavi Region, Tanzania (Katavi-Rukwa Management Plan 2002; Figure 2). The Park was established in 1974 to protect a great diversity and abundance of large mammals that collect near rivers and floodplains during the dry season (Caro 1999a, b; 2003). These floodplains are connected by the Katuma River that rises to the northwest and outside of Katavi National Park: it feeds Lake Katavi, the Katisunga floodplain and Lake Chada before draining into the Kavuu River and eventually into Lake Rukwa (Figure 2).

Katavi National Park is administered and patrolled by TANAPA. The other major protected area in the Katavi-Rukwa ecosystem is the 4323km2 Rukwa Game Reserve that lies to the east and south of the National Park (Katavi-Rukwa Management Plan 2002). It is administered by the Wildlife Division but is patrolled less frequently. To the south of these protected areas is Mpimbwe Division with a rapidly growing human population that has recently witnessed an influx of cattle from Kigoma, Tabora and Mwanza Regions (Borgerhoff Mulder et al. 2007). Consumption of bushmeat is widespread in Mpimbwe (Mgawe et al. 2012) with people hunting in Katavi National Park and Rukwa Game Reserve because large mammals have largely disappeared around villages.

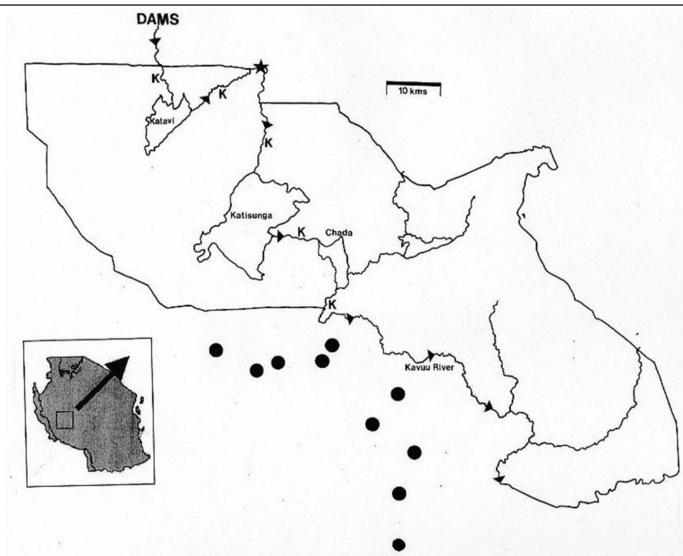

Figure 2. Map showing boundaries of Katavi National Park with its major river and principal floodplains (Katavi, Katisunga and Chada). K denotes the Katuma River and arrows mark the direction of flow. Location of Sitalike (TANAPA headquarters and position of the rainguage) is shown as a star. The location of the dams and the principal villages (circles) in Mpimbwe are also shown.

Data collection

Between 1995 and 2011, changes in large mammal populations in Katavi National Park were assessed by regularly driving four vehicle transects along the same minor tracks usually twice each dry season (1-3 times) (see Caro 2011). Mammals were recorded up to a distance of 500m from the centre of the transect (see Caro 1999a,b,c for details) and total numbers of each species were simply divided by lengths of transects to give the number of individuals/km. These population estimates were then averaged across transects and within each year. To reduce variability in the data inherent in vehicle transects (Caro 2011), running averages were calculated for each year that transects were driven by averaging the number of individuals/km that year with those counted in the previous and subsequent transect years and dividing by 3. For the first year (1995) an average was taken for 1995 and 1996; for the last year (2011) an average was taken for 2011 and 2010.

Rainfall records were taken from the rain gauge at the Park Headquarters at Sitalike; these began in January 1997. Again, 3-year running averages were used in analyses.

Poaching pressure was determined from Sitalike headquarters records. The number of poachers who were arrested and who escaped was divided by the number of rangers assigned to the Park each year to give an index of poaching pressure, July to June. Three-year running averages of poaching pressure for a given year, the previous year and following year were calculated to conform to running averages of species population estimates.

Local dams were first built in 1999 northwest of KNP in the catchment basin of the Katuma River (see Figure 2) to irrigate small scale rice fields; they were enlarged, reinforced and increased in number until 2003 when TANAPA authorities noticed a decline in water flow. Monthly water heights at Sitalike Bridge were available for the years 1990-1993 and 2005-2010.

For analysis, we normalized the mammal transect 3-year running average population estimates for each species, the three year running average of poaching pressure, and the three-year running average of rainfall using a square root transformations + 0.5, and used a univariate general linear statistical model to examine the effects of poaching, dams (before and including 2003 vs after) and rainfall simultaneously for each species.

RESULTS

The height of water each month under Sitalike Bridge in the early 1990s was much higher than in the late 2000s in every month of the year ($N = 12$ months, Wilcoxon signed ranks test across 12 months of the year, $z = -3.061$, $p = 0.002$; Table 1).

Table 1. Mean monthly river levels of the Katuma River at Sitalike Bridge in meters

	1990-93	2005-10
January	1.15	0.30
February	1.26	0.44
March	1.46	0.78
April	1.75	0.94
May	1.63	0.80
June	0.99	0.52
July	0.60	0.35
August	0.43	0.18
September	0.39	0.04
October	0.32	0
November	0.53	0.04
December	0.86	0.16

Poaching pressure standardized by anti-poaching effort showed a steep rise between 1995 and 2011 (N = 13 transect years, rs = 0.919, p < 0.001; Figure 3).Rainfall did not change significantly between 1995 and 2011 (N = 11 transect years, rs = +0.027, NS).

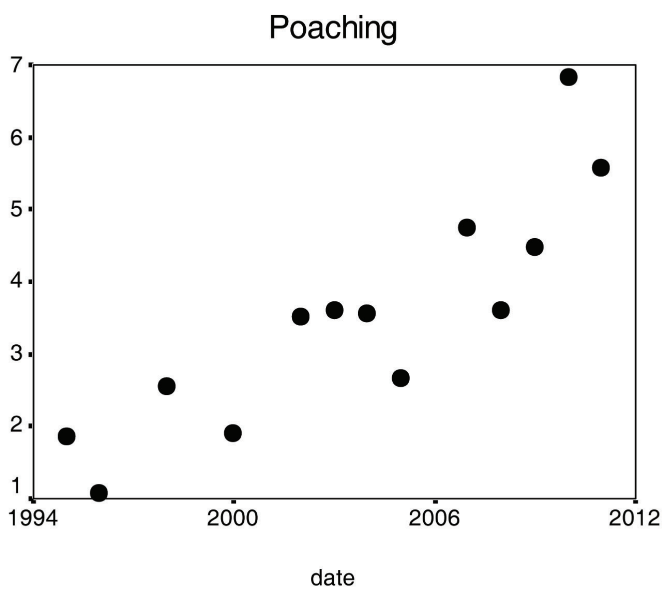

Figure 3. Changes in poaching pressure over time

We uncovered strong effects of both dam construction and poaching pressure on mammal population estimates in Katavi National Park but little evidence of effects of rainfall. Focusing simply on those species which were significantly declining based on vehicle transect data and for which statistical models were significant at the 0.05 level (i.e., being as conservative as possible), waterbuck ($F = 14.371$, $df = 1$, $p = 0.006$), hartebeest ($F = 7.691$, $df = 1$, $p = 0.028$), and spotted hyaena (Crocuta crocuta) ($F = 10.037$, $df = 1$, $p = 0.015$) were influenced only by damming. Elephant (Loxodonta africana) ($F = 14.162$, $df=1$, $p = 0.007$), common duiker (Sylvicapra grimmia) ($F = 13.179$, $df = 1$, $p = 0.008$), topi ($F = 11.936$, $df = 1$, $p = 0.011$) and lion (Panthera leo) ($F = 10.112$, $df = 1$, $p = 0.015$) were influenced only by poaching pressure, although the last species was also affected by rainfall ($F = 10.866$, $df = 1$, $p = 0.013$). Warthog were significantly affected by both damming and poaching pressure ($F = 10.304$, $df = 1$, $p = 0.015$; $F = 5.939$. $df = 1$, $p = 0.045$ respectively).

DISCUSSION

Aerial census data collected between 1977 and 2009 show significant declines in many species of mammal in the Katavi-Rukwa ecosystem and vehicle transects conducted between 1995 and 2010 support these conclusions (Caro 2011). At the same time measures of water flow through the Katuma River have declined (Table 1) and poaching pressure in Katavi National Park standardized for anti-poaching effort has increased (Figure 3) over similar time periods.

Mammals in Katavi National Park were affected by both poaching pressure and changing hydrology between 1997 and 2011 (Table 2). We found that common duiker, warthog, topi, elephant and lion decreases were associated with poaching pressure. Certainly, we know that poachers target both duiker and warthog as they are relatively numerous and easy to kill with muzzle loaders; warthog are frequently hunted by poachers simply to feed the porters who come in to carry meat out of the Park (Martin et al. 2013). As reported by poachers in Mpimbwe, duiker and warthog are second and third most sought after species (after impala). The findings regarding topi are more difficult to understand. It is perhaps not surprising that elephant numbers are associated with poaching pressure; despite a great success in capturing a renowned elephant poacher in Mpimbwe, there has been a consistent low level illegal offtake of elephants from Katavi National Park that is likely related to increased demand for ivory in China spurred by their growing economy (Stiles 2004; Milliken & Sangalakula 2012). Vehicle transects are a poor method of estimating lions and other predators but the association of a lion decline with poaching pressure is interesting because it backs up informal knowledge that young Sukuma men are hunting lions on foot in the Park for both commercial and traditional purposes (Borgerhoff Mulder et al. 2009). Waterbuck, warthog, hartebeest and spotted hyaena populations appear to be adversely influenced by damming. Waterbuck may be affected either because they favour watercourses or

Table 2. Summary of findings of this study.

Species observed	Significant population change based on vehicle transects?	Significant effect of rain?	Significant negative effect of poaching?	Significant negative effect of damming?
Common duiker	Decline		Yes	
Topi	Decline		Yes	
Elephant	Decline		Yes	
Lion	Decline	Yes	Yes	
Warthog	Decline		Yes	Yes
Waterbuck	Decline			Yes
Hartebeest	Decline			Yes
Spotted hyaena	Decline			Yes

because they graze on floodplains nearby. In contrast, warthog and hartebeest are dry country species so the association with damming is difficult to explain. Again vehicle transects are a poor way of estimating carnivore populations but spotted hyaenas may be adversely affected by reduced numbers of prey species due to drying conditions.

Interestingly, based on vehicle transects; we found that hippopotamus population estimates had increasing over time and were not affected by damming. Management is often concerned about potential hippopotamus die-offs at the end of the dry season in Katavi but our data show that such worries may be unfounded.

The findings presented here are preliminary in that we do not have robust measures of water height or flow throughout the Park's river system; measurements have been attempted but information is very difficult to collect. Nor do we have knowledge of the true numbers of animals taken by poachers. Nonetheless, our findings indicate that poaching and dam construction are both serious problems for the large and mid-sized mammals living in Katavi National Park. Therefore, the charismatic mammal species that Tanzanians and foreign tourists come to see in Katavi National Park are being impacted by both of these human-caused pressures. To the question "Is poaching or damming the most important problem facing KNP?", the answer is that they are both important. Some species are principally adversely affected by one factor, other species by the other factor, and some by both. Nevertheless, the Katavi-Rukwa ecosystem faces other challenges too: large herds of Sukuma cattle now graze in both protected areas, particularly Rukwa Game Reserve.

RECOMMENDATIONS

Our findings show that protected area authorities need to further reduce illegal hunting in the Park through traditional means of extending the number of anti-poaching patrols, conducting them over a wider area, and by using more informants. Beefing up TANAPA anti-poaching activities demands additional support from their head office – more rangers, more vehicles and a helicopter to get into inaccessible areas in the wet season are needed. There is an argument for starting foot patrols since much of the poaching occurs in the wet season when access by vehicles is very difficult. Furthermore, joint operations with both Wildlife Division game scouts and with the police are necessary given the scale of poaching – an estimated 115 poachers in Mpimbwe (Martin & Caro 2013) – and the growing demand for ivory. Nonetheless, education and providing alternative economic opportunities for communities living adjacent to the Park is also likely to be useful. There is a campaign for reducing Sukuma lion killing already underway in Mpimbwe.

In regards to locally constructed dams northwest of the Park, this is a problem for the Rukwa Water Basin Authority and local politicians. The Regional Commissioner of the new Katavi Region and District Executive Director should be encouraged to review and improve the management of water resources in the area taking entire watersheds into consideration but starting with the Katuma Basin. A twin policy of removing some of the dams and diverting water from the rice fields back into the Katuma River both need consideration. The water that feeds the Park – its lifeline – is being sidetracked and the long term future of mammals in Katavi National Park is being jeopardized by this development.

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