Tanzania Wildlife Research Institute (TAWIRI)

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PROCEEDINGS OF THE TENTH TAWIRI SCIENTIFIC CONFERENCE, 2ND - 4TH DECEMBER 2015, NAURA SPRINGS HOTEL, ARUSHA, TANZANIA

TANZANIA WILDLIFE RESEARCH INSTITUTE (TAWIRI)

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Editors

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Conference Theme

''The Future of Wildlife Conservation in the Face of Increasing Anthropogenic Demands''

MESSAGE FROM THE ORGANIZING COMMITTEE

TAWIRI Scientific Conferences are Biennial events. This year, we are marking the 10th TAWIRI Scientific Conference since we started in 2000. The 10th TAWIRI Scientific Conference under the Theme: "***The future of Wildlife Conservation in the face of Increasing Anthropogenic Demands***" aims at contributing to the global efforts on the long term sustainable wildlife conservation. It brings together, scientists, policy markers, conservationists, NGOs and Civil Society representatives from all over the world to present their findings, knowledge and get informed on the current knowledge, shortcomings and challenges facing wildlife resources in Tanzania and Africa at large. The conference will also highlight the links and challenges of the increased demands and overexploitation of wildlife resources and the future of wildlife conservation in Tanzania.

This year's Conference is expected to bring together about 250 participants from different parts of the world with diverse knowledge on wildlife conservation. The conference is a forum for dissemination of scientific information generated from various research studies whose aim is to provide ecological implication on wildlife conservation. It is expected that the recommendations generated from this conference will not only improve and safeguard our wildlife resources within the current increasing antropogenic demands over wildlife resources but also devise a way on how better communities can sustainably utilize the ecosystem services.

On behalf of the TAWIRI Management, Organizing Committee of the 10th TAWIRI Scientific Conference is honoured and pleased to invite all scientists, conservationists, government officials and representatives of NGOs and Civils Societies organizations to this important forum.

ORGANIZING COMMITTEE MEMBERS

1.	Dr. Maurus Msuha	Chairman
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3.	Dr. Stephen Nindi	Deputy Secretary
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SPEECH OF THE DIRECTOR GENERAL DR. SIMON MDUMA AT THE OFFICIAL OPENING OF THE 10TH TAWIRI SCIENTIFIC CONFERENCE AT NAURA SPRINGS HOTEL - ARUSHA, DECEMBER 2ND, 2015

Dr. Adelhelm Meru, Permanent Secretary, Ministry of Natural Resources and Tourism,

Dr. Nebbo Mwina representing the Ag. Director of Wildlife,

Mr. Allan Kijazi, Director General, TANAPA,

Dr Freddy Manongi, Conservator NCAA,

TAWIRI Management Team,

Conference Sponsors,

Conference Participants,

Ladies and Gentlemen

Good morning

Guest of honor,
First of all, allow me to thank you for accepting our invitation to officiate the opening of the 10th TAWIRI Scientific Conference of 2015 despite your tight schedule. On behalf of TAWIRI Management, I would like to express my sincere gratitude to you for your moral and material support to our Institute.

Honorable Permanent Secretary,
This conference has brought together about 250 participants from around the world, including long-term wildlife research scientists and young scientists. Let me express my sincere appreciation to all participants for their attendance to this important conference, special thanks to those who have traveled from far away.

Honorable Permanent Secretary,

It is worth noting that the management of our natural resources within and around protected areas in Tanzania is the distinctive responsibility of the Wildlife Division, Tanzania National Parks, Ngorongoro Conservation Area Authority and Tanzania Forestry Services. For these management authorities to achieve sound management plans, appropriate scientific information on the status of these wild resources is of paramount importance. Given this fact, there is a need for more support to the work done by TAWIRI and research in general. I acknowledge the strong support and collaboration from wildlife management authorities, conservation organizations and private sector that have been supporting us to achieve our goals. I acknowledge their presence today as this gives TAWIRI more strength and courage in fulfilling its mandatory roles.

Honorable Permanent Secretary,

TAWIRI Scientific Conferences are Biennual events that aim at bringing together prominent and up-coming wildlife scientists and conservationists from all over the world to disseminate research findings through presentations and talks and by exchanging information about research and experience on research for wildlife conservation. Continuation of these conferences provides evidence that TAWIRI is fulfilling its mandate. Thus, research findings presented by wildlife scientists in these gatherings is one among many other ways by which TAWIRI disseminates scientific information to stakeholders charged with responsibility of wildlife conservation.

Honorable Permanent Secretary,

Currently we understand that, the country is facing increasing wildlife conservation challenges, such as elephant poaching, increasing human population, encroachment into protected areas and loss of wildlife habitats, illegal resource harvest, reduced water availability for wildlife, spread of alien and invasive species, diseases and climate change. All these together have resulted into wildlife population decline as compared to the situation in the past. Thus more scientific information is needed on how to improve livelihood of communities around protected areas by enhancing economic growth, conserving our natural resources and reducing human pressure on wildlife including poaching.

Honorable Permanent Secretary,

There has been a change in terms of human resources within the Institute since its establishment. The number of bial researchers increased from 4 in 1980 through 1990s to 46 to date. This number is still inadequate due to the vast geographical areas to be covered, diversity of species and the numerous challenges affecting wildlife conservation, TAWIRI is working in close collaboration with other researchers from all over the world. This is witnessed through the number of projects that were registered by the Institute during the financial year 2014/2015, where a total of 135 projects and 549 research scientists were registered and coordinated. I am pleased to inform you that the number of Tanzanian research scientists has been increasing for the past three years. For example, in the financial years 2012/2013, 2013/2014 and 2014/2015 the number of Tanzanian research scientists were 125, 166 and 189 respectively.

Further more, the Institute in collaboration with other institutions is also managing the following projects:

1. Rabies control project around Serengeti ecosystem (Funded by Biotechnology and Biological Sciences Research Council through University of Glasgow UK)
2. Research on Ecology and Epidemiology of Rift Valley Fever in the Serengeti Ecosystem (Funded by Wellcome Trust UK through Afrique One Consortium).
3. Poverty and ecosystem Impacts of payment for wildlife conservation initiatives in Africa: Tanzania's Wildlife Management Areas (PIMA), funded by ESPA
4. Management of human-carnivore conflict and community adaption to climate change, funded by UNDP
5. Parasites, bacteria and viral pathogens of wildlife in Tanzania (Funded by National Research Foundation of Korea through Korea National Research Resource Centre)
6. Serengeti Wild-dog Project (Funded by TANAPA, NCAA, Grumeti Fund, Bio-Top Tz Ltd and Institute of Science and Technology Norway)
7. Tanzania Carnivore Project (Funded by Darwin Initiative)
8. CUT (Conflict, Use and Threats) Plan for large Carnivore Management in Tanzania (Supported Darwin Initiative)
9. Human-Elephant Conflict mitigation around Mikumi National Park (Funded by World Society for Protection of Animals)
10. Wildlife studies in Tanzania. Africa-Japan-Core to core Programme (Funded by Japan Society for Promotion of Science)
11. Conservation Research on East African Threatened Ecosystems (CREATE) (Funded by European Union through Frankfurt Zoological Society).
12. Linking biodiversity, ecosystem functions and services in the Greater Serengeti-Mara ecosystem (GSME)-drivers of change, causalities and sustainable management strategies (Funded by European Union)

13. Assessment of Visitor Facilities and Tourism Experience in Kilimanjaro and Serengeti National Park (Funded by TANAPA)
14. Tarangire-Manyara wildlife corridor vegetation classification and mapping project (Vollmar Natural Lands Research Group)
15. Effects of Cultivation on Vegetation in NCAA (Funded by NCAA)

Honorable Permanent Secretary,
Despite the aforementioned achievements, the Institute has been suffering from a series of challenges, including insufficient funding, inadequate staff in terms of number and skills and inadequate infrastructure and working equipment. Insufficient funding has resulted into over-dependence on foreign donors leading to difficulties in implementing our domestic research priorities, which in-turn has resulted into geographical mismatch of research project distribution; in that, most of them are focused in the Northern zone where donors prefer.

Honorable Permanent Secretary,
For those who attended the previous TAWIRI Conferences, will recall that, conference themes have been changing to reflect the current situations and needs for wildlife conservation. This year's theme is "**Wildlife Conservation in the face of Increasing Anthropogenic Demands".** This theme was chosen to provide an insight on the ongoing global conservation challenges resulting from human demands over the use of natural resources and how they impact wildlife survival. Indeed, current environmental and economic changes brought through increased human population are of great concern to mankind today than ever before.

In this conference, about 127 research papers will be presented and discussed. Full manuscripts will be submitted to TAWIRI for review process and those that qualify will be published in TAWIRI conference proceedings as it has been done before. Through this, even those who failed to physically attend the conference will be able to receive scientific information that will support conservation of wildlife resources. I believe that, if used properly, these findings will contribute significantly to the sustainable wildlife management in Tanzania and at regional level.

Honorable Permanent Secretary,
TAWIRI is mandated to carryout, coordinate and supervise wildlife research in the United Republic of Tanzania. For TAWIRI to fulfill this mandate adequate funding is needed. I am pleased to inform you that various conservation

donors and wildlife management authorities have been supporting TAWIRI to archive its goal. We are grateful to the Wildlife Division, Tanzania National Parks, Ngorongoro Conservation Area Authority, Tanzania Forest Services, Commission of Science and Technology (Tanzania), the Biotechnology and Biological Sciences Research Council of United Kingdom, National Research Foundation of Korea, Grumeti Fund, Norwegian University of Science and Technology, Darwin Initiative of UK, Japan Society for Promotion of Science (JSPS), Frankfurt Zoological Society (FZS) and Wildlife Conservation Society who are currently funding TAWIRI's projects and priority activities. However, core funding to the Institute comes from the Government of Tanzania, thus, I thank your Ministry and all the donors for financial and material support, and request your good office to continue supporting TAWIRI in fulfilling its mandate.

Honorable Permanent Secretary,
Organizing TAWIRI Scientific conference that takes place after every two years, need large amount of funds. Many donors and collaborating Institutions have been supporting and sponsoring TAWIRI Scientific Conference. We are pleased that there has been an increasing interest in sponsoring this conference, this year's conference is sponsored by your Ministry of Natural Resource and Tourism, Wildlife Division, Tanzania National Parks, Ngorongoro Conservation Area Authority, Grumeti Fund, Wildlife Conservation Society, The Nature Conservancy, World Elephant Centre, Tanzania Association of Tour Operators (TATO), University of York, Tanzania Breweries, Norwegian University of Science and Technology and Naura Spring Hotel. We thank them all for their support and we hope they will continue to support us not only for these conferences, but also for other activities of the Institute. Allow me also to thank the Management of TAWIRI and the Conference Organizing Committee for the efforts put in organizing and making it happen.

Honorable Permanent Secretary,
With these remarks, I have great honour to welcome you to officially open the Tenth TAWIRI Scientific Conference.

THANK YOU

SPEECH OF THE PERMANENT SECRETARY, MINISTRY OF NATURAL RESOURCES AND TOURISM DR. ADELHELM MERU AT THE OFFICIAL OPENING OF THE 10th TAWIRI SCIENTIFIC CONFERENCE AT NAURA SPRINGS HOTEL, ARUSHA, DECEMBER 2, 2015

Director General, Dr. Simon Mduma

Management of TAWIRI,

Conference Participants,

Distinguished Guests,

Ladies and Gentlemen

First and foremost, allow me Director General to extend my sincere gratitude to you, and the Management of TAWIRI for inviting me to officiate the opening of this Tenth TAWIRI Scientific Conference here in Arusha for the first time. I feel greatly honoured.

Conference Participants, Ladies and Gentlemen,
I wish to take this opportunity to welcome all of you to Arusha and to this conference in particular. A special welcome is extended to colleagues who have travelled all the way from outside Tanzania to come to attend this conference. Your presence is highly appreciated and signifies your regard and support to TAWIRI and your commitment to wildlife conservation in general. You are most welcome and it is my hope that you will find the environment conducive enough for your serious deliberations in the next three days. 'KARIBUNI SANA".

Conference Participants, Ladies and Gentlemen,
The mandate of TAWIRI is to conduct and coordinate wildlife research carried out in Tanzania and disseminate research findings to stakeholders for conservation purposes. The TAWIRI scientific conferences have therefore been useful in enabling the Institute to fulfil this important function. In addition, I am pleased to note that the revised Tanzania Wildlife Research Agenda, which is a product of TAWIRI, wildlife management authorities and you wildlife research scientists, has put forward eight priority research areas. My understanding is that one of the objectives of the TAWIRI Scientific

Conferences is to continually provide updated information on the priority research areas so that this information can guide development of effective strategies for conservation of wildlife resources. I am also pleased to note that TAWIRI has ensured that proceedings of these conferences are published and disseminated to end-users. I have been informed that, proceedings of the 9th TAWIRI Scientific Conference have been printed, distributed and posted on the TAWIRI website.

Conference Participants, Ladies and Gentlemen,
The Ministry of Natural Resources and Tourism recognises the importance of TAWIRI Scientific Conferences as a platform to disseminate research findings that were carried out and continue to be carried out in the country and share this information with wildlife stakeholders. In this regard, the Ministry will continue to support these conferences to the best of its ability.

Conference Participants, Ladies and Gentlemen,
The Ministry of Natural Resources and Tourism also recognises that we have a wide range of stakeholders in the wildlife sector who are end-users of the findings generated by researchers; your attendance in these conferences is of paramount importance. Let me take this opportunity to request wildlife managers, tour operators, conservationists and development partners, just to mention a few, to ensure that they attend these scientific conferences organised by TAWIRI in order to enrich their knowledge of wildlife resources for promoting sustainable conservation and development in Tanzania.

Conference Participants, Ladies and Gentlemen,
The theme of this conference is "**Wildlife Conservation in the face of Increasing Anthropogenic Demands**". This theme is timely not only in Tanzania but also the African continent as a whole. The African continent for nearly a decade has witnessed declining wildlife numbers particularly elephants. Elephant poaching has become one of the leading wildlife crimes in the world. Elephant range states in Africa have lost and continue to lose their remaining elephants mainly due to poaching. Increasing demand for ivory products in countries such as China, Thailand, Vietnam and Philippines has escalated the poaching crisis. While poaching has significant negative impact on elephants and populations of other wildlife species, including rhinos, we should not forget that other socio-economic demands such as loss of wildlife habitats due to land use change driven by expanding human population also affect wildlife populations.

Over the past four decades the natural rangeland in Tanzania has been decreasing in size due to increase in human and livestock populations. For example, human population has increased from 9 million in 1961 to over 45 million in 2012. During the same period, the number of traditional cattle increased from 3 million to 21.3 million in 2011, hence the demand for more land for settlements, agriculture and grazing domestic stocks. Not to mention conversion of wild lands into big state farms, mining, infrastructure development and expansion of cities and towns.

In principle, as human populations grow, so do the resource demands imposed on ecosystems. The ever increasing demand for land causes protection of protected areas to be politicized. There is a danger of forgetting the fundamental principle that natural resources are not invulnerable and indefinitely available. In this regard, I urge wildlife scientists to continuously provide scientific information to the Government, wildlife management authorities, conservation and development partners that will guide development of effective conservation and development strategies.

Conference Participants, Ladies and Gentlemen,
When you think of Africa, wildlife is usually one of the striking resources that come to our minds. Wildlife resources have and continue to contribute to economic growth of many countries in this continent. For example, in Tanzania tourism, which is predominantly wildlife based is now the leading sector in foreign revenue earnings contributing about 17% of the GDP. Let me take this opportunity to ask wildlife stakeholders in Tanzania to work together to ensure that wildlife resources are properly protected for the benefits of the current and future generations.

Conference Participants, Ladies and Gentlemen,
We are currently in a situation where we are trying to balance the need for economic development and conservation of biodiversity. I think you will agree with me that when people are hungry because of uncertain income, they are likely to destroy the environment in which their livelihood depends on. Tanzania is also endowed with rich and diverse renewable and non-renewable natural resources, yet our people remain among the poorest in the world. Improving our people's welfare while ensuring sustainable use of our natural resources is a challenge that needs to be addressed.

I therefore, urge wildlife management authorities, research scientists and conservationists to take this as a challenge and start preparing future conservation plans for our wildlife resources under these circumstances.

Conference Participants, Ladies and Gentlemen,
While I commend scientists for their contribution towards wildlife conservation through generation of scientific knowledge, let me take this opportunity to pose a few challenges.

First, I call on wildlife researchers to diversify their research areas and priorities in order to take on board issues of socio-economic development. I understand that most of the long-term research work has concentrated in selected protected areas in the country, northern Tanzania in particular. Moreover, these studies have been mainly on some groups of animals or subjects. I therefore call for wildlife scientists to ensure that less studied areas such as the southern circuit including the Selous, Ruaha-Rungwa and Katavi-Rukwa ecosystems are also given due attention in line with the Tanzania Wildlife Research Agenda. This would contribute towards enhancing conservation of wildlife in these areas.

Second, I call upon wildlife research scientists to consider investing in understanding impacts of socio-economic development activities to wildlife conservation in this country and find ways of mitigating such impacts in line with the theme of this conference. For example, can we achieve socio-economic development while maintaining ecological integrity of important wildlife ecosystems? Will socio-economic development activities outside protected areas promote co-existence of people and wildlife? Are there policy or legislative issues that hinder effective conservation of wildlife?

Conference Participants, Ladies and Gentlemen,
My Ministry recognizes the importance of wildlife research and will therefore continue to support the Institute through provision of basic and operational funding. At the same time, let me take this opportunity to say that TAWIRI needs to find other sustainable mechanisms of funding research and related works. This may be achieved through development of competitive research projects by collaborating with other institutions within and outside Tanzania.

Your initiatives on finding other sources of funding should also include (*i*) provision of consultancy services at a fee and, (*ii*) development of demand-driven research projects that have direct impact towards solving national problems including poverty reduction and sustainable conservation.

Conference Participants, Ladies and Gentlemen,
I am told that contributions from wildlife management authorities to TAWIRI's core activities have been declining over the years. Given the importance of wildlife research for sustainable conservation of wildlife in Tanzania, I ask wildlife Management Authorities to continue providing support to TAWIRI. I understand that in the New Wildlife Act of 2009 has a provision for Management Authorities to provide financial support to TAWIRI, The College of African Wildlife Management and Pasiansi Wildlife Training Institute. In this regard, I ask the Director of Wildlife and applicable institutions to work on draft regulations and submit to the Ministry for implementation of this provision.

Conference Participants, Ladies and Gentlemen,
Let me also ask development agencies and partners on the need to support research work. I am grateful to note that a positive development already exists with the following donors: European Union, Darwin Initiative, Ecosystem Service for Poverty Alleviation (ESPA), United Nation Development Programme (UNDP), USAID, Frankfurt Zoological Society, Ngorongoro Conservation Area Authority, Tanzania National Parks, Wildlife Division, Eastern Arc Endowment Fund, Grumeti Fund, Centre for Biothreat Preparedness, Safari Club International Foundation, Vollmar Natural Lands Research Group, TANESCO, Bio-Top Tanzania Ltd and Vulcan Inc of USA.

Conference Participants, Ladies and Gentlemen,
I understand that organizing a conference like this one is very expensive. Therefore, I would like to thank the Wildlife Division, Tanzania National Parks, Ngorongoro Conservation Area Authority, Grumeti Fund, Wildlife Conservation Society, The Nature Conservancy, World Elephant Centre, Tanzania Tour Operators (TATO), University of York, Norwegian Institute of Science and Technology (NTNU), Naura Springs Hotel and the Ministry for funding this conference. I am happy to note that participants for the scientific conferences and paper presentations have been increasing steadily for the past nine years. This testifies that a conference like this plays a regional and international role in bringing together all people working to

generate new knowledge towards enhancing conservation of our wildlife resources.

Conference Participants, Ladies and Gentlemen,
Let me conclude my remarks by wishing all participants a fruitful scientific conference. For participants coming from outside Tanzania, I would like to welcome you to the "Land of Kilimanjaro and Zanzibar", and specifically to Arusha – 'The City of Destiny', which is surrounded by a diversity of within easy reach attractions including Arusha, Lake Manyara, Tarangire and Serengeti National Parks, Ngorongoro Conservation Area, Olduvai Gorge and also Meru and Kilimanjaro mountains. Therefore, I urge you to spare some days after the conference to visit some of these fascinating tourist attractions in Tanzania. Indeed, you will find a home away from your home.

With these remarks, I now have the pleasure to declare the Tenth TAWIRI Scientific Conference officially opened.

THANK YOU

CLOSING REMARKS BY DR. NEBBO MWINA, ASSISTANT DIRECTOR RESEARCH, STATISTICS AND TRAINING AT THE 10TH TAWIRI SCIENTIFIC CONFERENCE HELD AT NAURA SPRINGS HOTEL - ARUSHA, DECEMBER 4TH, 2015

Director General - TAWIRI, Dr. Simon Mduma,

TAWIRI Management Team,

Conference Participants,

Ladies and Gentlemen,

I feel honored to stand before you, as we mark the end of our three day's conference exchanging information, findings and experiences of research conducted in different places all aiming to conserve our wildlife resources. We all have witnessed the spirit of sincerity and common concern on the need for improving the welfare of communities around protected areas as well as ensuring sustainable use of our natural resources that was expressed in response to the presentations and subsequent discussions, which were very much interactive.

Ladies and Gentlemen,
On this very note, I wish to thank the conference organizers (TAWIRI), for a well thought conference theme "The future of Wildlife conservation in the face of Increasing Anthropogenic Demand" which we as scientist need to find solutions from emerging challenges of increasing anthropogenic activities and make sure wildlife conservation competes with other economic activities such as livestock, agriculture and mining. We scientist need to show/convince the public that wildlife conservation is a lifetime economic incentive while these other economic activities are short lived and have adverse effects to the environment.

Ladies and Gentlemen,
I also wish to thank all those who made this meeting a success in every aspect and the participants who presented in this conference through seminars, posters and talks.

I am pleased to note that in this conference there was a total of 125 presentations (see appendix) out of which, 90 were oral presentations, 20 poster presentations and 15 seminar presentations. I am told this was the first time TAWIRI Scientific Conference had seminars presentations running parallel to plenary presentations. This has given participants a wide range of choice at the same time increase diversity of research topics.

Ladies and Gentlemen,
A number of critical challenges were raised and critically discussed. If I may recap on some of the challenges mentioned in the discussion they include the need to strengthen a network in research and information sharing among the institutions involved in wildlife conservation. The discussions also deliberated on ways of strengthening collaborations among wildlife management authorities, scientists, conservation and development partners for guiding effective conservation strategies. You also had a chance to deliberate on impacts of socio-economic development activities to wildlife conservation in this country and suggesting ways of mitigating them.

Ladies and Gentlemen,
I take this opportunity to reiterate the need for diversifying your research areas to take on board issues of socio-economic development and your research to cover less studied areas such as the southern circuit that includes Selous, Ruaha, Rungwa and Katavi – Rukwa ecosystems.

Ladies and Gentlemen,
I do not wish to take much of your precious time considering we've had three days of intense presentations and discussions, but it is sufficient to say they were very productive in laying out the foundation for sustainable conservation of our wildlife resources.

With these remarks I now have the honor to declare the Tenth TAWIRI Scientific Conference officially closed. I wish to take this opportunity to wish you a safe journey back home for those who have travelled, very Merry Christmas and Happy New Year 2016.

THANK YOU

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AKNOWLEDGEMENT

Tanzania Wildlife Research Institute (TAWIRI) is grateful to acknowledge the financial support from the Government of Tanzania and the following authorities, organizations, institutions and companies and wish to thank them for their contribution.

POPULATION, DISTRIBUTION AND ACTIVITY PATTERN OF VULTURES IN THE SERENGETI ECOSYSTEM, TANZANIA

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ABSTRACT

Vultures are scavenging birds that feed mostly on carcasses and play an important ecological role in various ecosystems. Vultures' population in Tanzania is thought to be declining probably due to habitat loss caused by land use changes, climate change, poisoning by poachers and livestock keepers. A study to investigate population status (species diversity, abundance and distribution) of vultures in the Serengeti ecosystem was conducted between July 2011 and January 2012. Opportunistic road survey method was employed with gentle approach by a vehicle to identify and enumerate sighted vultures within an estimated distance of 500m on either side of the road. Epi Info software was used for data analysis using χ^2-square test to compare variables at a critical probability of 0.05. A total of 541 individual vultures were observed. African White-backed vulture (Gyps africanus, 66.0%) and Rüppell's-Griffon vulture (Gyps rueppellii, 23.7%) were the most frequently encountered (X^2>12.62, p<0.0003) than *Hooded vulture (Necrosyrtes monachus, 5.4%), Lappet-faced vulture (Torgos tracheliotos, 4.8%) and Palm-nut vulture (Gypohierax angolensis) was the least (0.2%). Intriguingly; White-headed vulture (Trigonoceps occipitalis), Bearded vulture (Gypaetus barbatus) and Egyptian vulture (Neophron percnopterus) were not sighted and there were no vultures found dead. Majority of sightings were in the evening (50.8% than morning and afternoon each with 24.6% (X^2>14.27, p<0.0002). Presence of wildebeest (Connochaetus taurinus, 34%) and zebra (Equus burcheli, 21%) significantly affected the foraging potential of vultures whereby were frequently observed at close proximity (X^2>4.22, p<0.0044) than the presence of buffalo (Syncerus caffer, 7%). As fa as activities of vultures are concerned, most vultures' (42%) were anxiously watching wild animals around (X^2 >13.65, p<0.0002) than scavenging (18%), resting (18%), flying (12%) or nesting (10%). Vulture distribution varied with migratory ungulates (X^2>8.0988, p<0.0044). This study justifies a need to establish a long-term vultures' monitoring network around the Serengeti-Mara ecosystem and Tanzania.*

Key words: *Activity, population, distribution, Serengeti, vulture.*

INTRODUCTION

Vultures are birds of prey that play an important ecological role of maintaining ecosystem health by feeding mostly on carcasses of wild and domestic animals. There are more than 20 species of vultures in the world that had a broader historical distribution world-wide of which eleven species of vultures are endemic to Africa (Stattersfield and Capper, 2000; BirdLife-International, 2004; Anderson and Hohne, 2008). Serengeti ecosystem is a home to eight (8) vulture species namely African White-backed vulture (AWBV) *Gyps africanus* Salvadori 1865, Rüppell's-Griffon vulture (RGV) *Gyps rueppellii* Brehm 1852, Hooded vulture (HV) *Necrosyrtes monachus* Temminck 1823, Lappet-faced vulture (LFV) *Torgos tracheliotos* Forster 1791, Palm-nut vulture (PNV) *Gypohierax angolensis* Gmelin 1788, White-headed vulture (WHV) *Trigonoceps occipitalis* Burchell 1824, Egyptian vulture (EV) *Neophron percnopterus* Linnaeus 1758 and Bearded vulture (BV) *Gypaetus barbatus* Linnaeus 1758. Mundy *et al.* (1992) investigated vultures of Africa and estimated their population sizes at 100,000 pairs or 270,000 individual AWBV globally; 11,000 breeding pairs or 30,000 individual RGV (3,000 breeding pairs in Tanzania and 2,000 in Kenya); 8,000 individual LFV in Africa; 80,000 pairs of PNV in Africa; 2,600–4,700 pairs and 7,000–12,500 individuals of WHV globally; and 20,000 individual EV augment by Palaearctic migrants during the Boreal winter whose population excluding Africa was estimated at about 2,750 pairs in the mid 1970's (Cramp and Simmons, 1980). BirdLife-International (2004) estimated population of BV between 10,000 and 100,000 individuals globally but there were no records of HV (Monadjem *et al.*, 2004). The International Union for Conservation of Nature (IUCN) Red List has categorized four (AWBV, HV, RGV and EV) of the eight vulture species that are found in the Serengeti ecosystem as endangered, LFV and WHV as vulnerable while PNV and BV as least concern (IUCN, 2013).

Population of vultures is declining all over the world (Anderson, 2000; Gilbert *et al.*, 2002; Prakash *et al.*, 2003; Thiollay, 2006a, 2006b, 2007; Bamford *et al.*, 2009; Ogada *et al.*, 2012; Kendall *et al.*, 2014). For example, an average decline of 42% was reported in West Africa (Rondeau and Thiollay, 2004; Botha *et al.*, 2012). As for other wildlife species, habitat loss as a result of land use changes has exacerbated the situation. In addition, collisions, drowning, electrocution and poisoning have also been negatively impacting populations of vultures further contributing to the declining trends world-wide (Gilbert *et al.*, 2002; Anderson and Hohne, 2008; Kendall *et al.*, 2012; Ogada *et al.*, 2012). Degradation or modification of habitat structure influences availability and distribution of biotic and abiotic natural resources including wild animals, natural tropical grassland, forest and woodlands that have been increasingly restricted to protected areas (Metzger *et al.*, 2005; Reed *et al.*, 2009; Ogada *et al.*, 2012). As a result, vultures have been seeking refuge to inside or around these protected and few unprotected areas, where their low abundance and diversity are also increasingly becoming common (Herremans and Herremans-Tonnoeyr, 2000; Thiollay, 2006a, 2006b; Murn and Anderson, 2008; Virani *et al.*, 2011; de Visser *et al.*, 2011; Nkwabi, 2014). Although impacts of the world-wide climate change on vulture populations is not well understood, climate may negatively influence incubation and brooding time, vegetation and populations of other wild animals; hence, contributing to further decimate these birds of prey. Ability to travel long distances of up to 240km in search of food and 1,100km away from their ranging site (Houston, 1974; Kendall *et al.*, 2014) makes vultures prone to an array of risks leading into their succumbing to unfriendly human activities. By virtue of their hovering over dead animals including poachers' kills, vultures expose poachers in the wild to the anti-poaching staff who always search for and apprehend the poachers. As a coping strategy, poachers have embarked on purposive poisoning of vultures to deter their detection and apprehension in the wild or make business of vulture's body parts for traditional medicine in different parts of Africa. The vultures have been associated with magic power to render people with ability for future prediction (Cunningham, 1990) and all species are equally important in such mythical beliefs (Bamford *et al.*, 2009). Vultures have also been falling victims of unintentional killings secondary to retaliatory poisoning of wild predators after attacking and/depredating domestic animals and/ or humans mostly in the human-wildlife interfaces. As reported elsewhere (Houston, 1990; Ogada and Buij, 2011; Ogada *et al.*, 2012), Our experiences show that Serengeti ecosystem is not an exception as several events of poisoning these birds mainly using a broad-spectrum insecticide (carbofuran) have been experienced (Kilewo, 2010; personal communication; Keyyu, 2011; unpublished data).

Despite the fact that some ornithological studies have been carried out in the Serengeti ecosystem (Pennycuick, 1976, 1983; Houston, 1990; Gottschalk *et al.*, 2007; Mwangomo *et al.*, 2007; Virani *et al.*, 2010; Nkwabi *et al.*, 2011; Virani *et al.*, 2011; Kendall *et al.*, 2014), very few focused on vultures. Generally, these birds have been given little attention and scanty information on status of population, distribution and activities of vultures is available. With inadequate information, it is very difficult to reliably establish population trends and devise future conservation strategies for a given wildlife species. The current study was geared to explore population status - population size, species diversity, distribution and activities of vultures in the Tanzanian part of the Serengeti-Mara ecosystem. This study was undertaken in the Serengeti

National Park (SNP) and included some parts of Grumeti, which falls under Ikorongo-Grumeti Game Reserve (IGGR). The main objective was to generate baseline information to help understanding the population status of vultures in the Serengeti-Mara ecosystem. It is our hope that this study will positively contribute to enhance conservation of vultures in Tanzania and East Africa as a whole.

MATERIALS AND METHODS

This study was undertaken within two protected areas in the Serengeti-Mara ecosystem in Tanzania namely SNP and Grumeti, which is part of IGGR. Undertaken between July 2011 and January 2012, this study used four main road transects to establish population, species, distribution and activities of vultures in SNP and Grumeti while covering both dry and short rain seasons. The transects surveyed with their total length in brackets include: Fort Ikoma-Seronera-Golini (128km), Fort Ikoma/Seronera junction-Ndabaka (140km), Fort Ikoma-Nyasiroli-Kirawira B (60km) and Banagi–Kleins -Nyamalumbwa (120km). Enumeration and identification of vulture species was restricted within an estimated distance of 500m on either sides of the roads. The vultures were gently approached by a vehicle and number of individuals counted and classified into respective species in line with recording their locations using a GPS (GPSmap60CSx, Garmin) and activities (flying, scavenging, resting and nesting). Wild animal species that were at close proximity to the vultures at the time of observation were also recorded so as the environments where the birds were (tree, ground, on carcass and in air). The data were organized using Microsoft Excel spreadsheet and the ArcGIS software version 10.1 was used for production of the distribution maps. Epi Info software was used for data analysis using χ^2-square test and Statcalc two-by-two contingency tables to compare variables at a critical probability of 0.05 (Lee *et al.*, 1984).

RESULTS

A total of 541 individual vultures representing five of the known eight vulture species in the Serengeti ecosystem were sighted (Figure 1). AWBV (66.0%) and RGV (23.7%) were the most frequently encountered species (X^2>12.62, p<0.0003) than HV (5.4%), Lappet-faced vulture (4.8%) while PNV was the least (0.2%). Intriguingly, WHV, EV and BV were not sighted and no vultures were found dead. Generally, the AWBV, RGV, HV and LFV were widely distributed almost all-over the study area (Figure 2 A-D). Some of the vultures were frequently encountered along Grumeti (14.8%) and Nyabeho (8.2%) rivers in Western and Northern parts of Serengeti National Park, respectively.

Vulture distribution matched with presence of migratory ungulates in close proximity namely wildebeests *Connochaetus taurinnus* (34%) and zebra *Equus burcheli* (21%, X^2>4.22, p<0.0044) than buffaloes *Syncerus caffer* (7%). Thomson's gazelle *Gazzela thomsoni* and black rhinoceros *Diceros bicornis* were the least wild animal species recorded at proximity to vultures with 3% and 2% of all the observations, respectively. Majority of vultures (72%) were on trees (X^2 >63.31, p<0.00001) than on the ground (16%) and flying (12%). With regard to activities, most of the vultures (42%) were anxiously watching wild animals around (X^2 >13.65, p<0.0002) than scavenging on carcasses (18%), resting/relaxing (18%), flying (12%) and nesting (10%). Noteworthy, majority of these birds of prey were sighted in the evening (50.8%) than morning and afternoon sessions, each with 24.6% (X^2>14.27, p<0.0002).

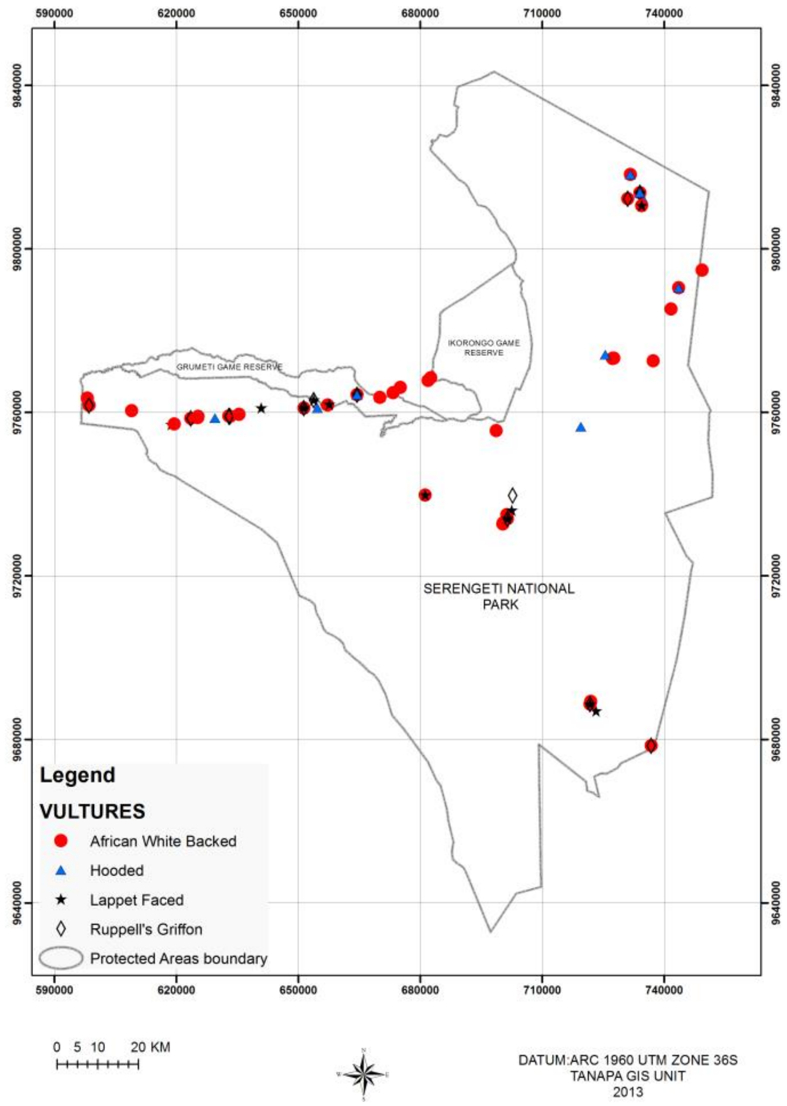

***Figure 1**: Study area map showing points where vulture where sighted in Serengeti National Park and Grumeti Game Reserve (GGR), Tanzania.*

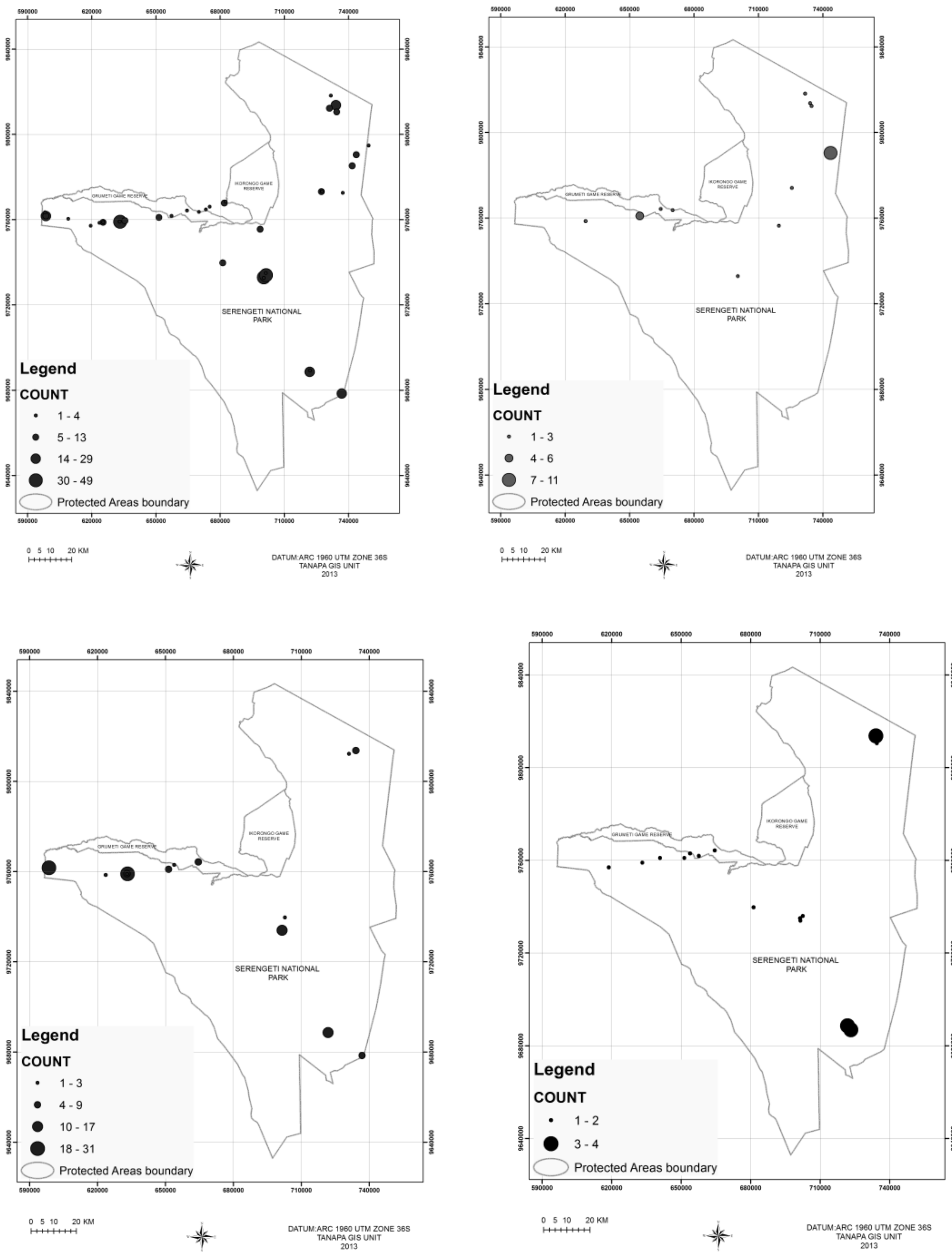

Figure 2: *Vulture species and distribution in the Serengeti National Park and Grumeti Game Reserve: African white backed (top left), Hooded (top right), Ruppell's Griffon down left) and Lapet-faced (down right).*

DISCUSSION

Among all the five vulture species observed, AWBV and RGV were the majority with significantly higher populations followed by HV and LFV. Mundy *et al.* (1992) and Virani *et al.* (2011) reported that AWBV were the most common species widely distributed in Africa. Habitat suitability is among key ecological attributes favouring existence and good performance of several wildlife species including vultures in the Serengeti ecosystem and elsewhere in the world. Trees are used by vultures not only for nesting but also as strategic high points for scanning around for food, roosting, breeding and resting. In the current survey, higher numbers and wide distribution of AWBV and RGV in the Serengeti ecosystem indicate their higher abundance as compared to the rest vulture species. Good performance of *Gyps* species was previously linked to availability of suitable trees and food/prey enough to comfortably sustain these birds of prey. In this study, vultures were found almost all over the study area though they more preferred areas with trees as compared to short grass plains. Majority of these birds were seen on *Acacia* trees while only a few were on other trees species. Vultures' preferential use of *Acacia* trees for nesting supports previous studies (Kemp and Kemp, 1975; Houston, 1976; Whateley, 1986). For example, *Acacia nigrescens* was mostly preferred by vultures for nesting in Kruger National Park (Kemp and Kemp, 1975). To some extents, our observation could be somehow influenced by biasness for Acacia trees dominate in SNP and Grumeti as compared to other species. Vulture nests were observed to concentrate in riparian vegetation as previously reported in Masai-Mara in Kenya (Virani *et al.*, 2011). In other studies elsewhere (Mundy et al.1992; Mundy 1997), tall trees such as *Acacia* spp, *Ficus* spp. and *Adansonia digitata* were used by vultures for both roosting and breeding.

In this study, only Palm-nut vulture (PNV) was sighted in central zone of Serengeti National Park while EV and BV were not sighted at all. These species seem to be very rare in the SNP and Grumeti Game Reserve. Most of the time, change in land use has been implicated in extirpation of some wildlife species; however, this is not the case as both SNP and GGR are wildlife-protected areas in Tanzania that have not experienced change in land use for some time now. One would have expected to see at least very few individual EVs and BVs failure of which most likely implies their actual rarity in the Serengeti ecosystem. This finding is in agreement with Virani (2011), who did not see EVs in 2003-2005 surveys and proposed their local extermination as a result of land use changes. Previously, however, Virani *et al.* (2011) recorded 22 EVs in

1976 and 1988 signifying a decline in population of vultures over the last thirty years in Masai Mara National Reserve (MMNR) in Kenya. The documented declines were 62% for HV, Gyps vultures 52%, LFV 50% and WHV 44% (Virani *et al.*, 2011). As the case is with the current study area, MMNR is Kenyan part of the Serengeti-Mara ecosystem; no wonder for the observations to overlap between the two countries. In addition, vultures exhibit variability in space and time usage in pursuit of their basic needs distribution of which is markedly influenced by climate. An annual rainfall gradient from about 500 mm in the dry South-eastern grassland plains to 1,200mm in the North-western region bordering Kenya (Sinclair and Arcese, 1995) has shaped vegetation and affects resource availability and distribution in the Tanzanian part of the Serengeti-Mara ecosystem. This gradient might have indirectly influenced both temporal and spatial distribution of various wildlife species including vultures making them temporarily unavailable at some localities. However, bigger datasets and wider coverage in terms of area and time are beyond those of the current study will be helpful to confidently conclude on the extirpation of the rarely sighted and/ none sighted vulture species. It is therefore recommend that more efforts be done to ascertain population status of the rarely sighted and the completely missed vultures and, if possible, make them flourish again.

Influence of migratory and non-migratory wildlife species on the distribution of vultures in the current survey was evident. With exception of the PNV, which is a specialized palm fruit eater, all the rest seven of eight vulture species documented in the Serengeti ecosystem do scavenge on animal carcases. In this survey, distribution of vultures was greatly associated with presence of migratory and non-migratory herbivores, especially in cool times of the day. Majority of the vulture sightings (63%) were linked with presence in close proximity of migratory mammals namely wildebeest, zebra and Thomson's gazelles. In relation to this observation, there is no doubt that vultures have been taking strategic positions to increase probability of success in securing their preys. Similar observation was recorded by Virani *et al.* (2010) that increase in food availability during the migration significantly matched with higher abundance of vultures in the Masai Mara ecosystem such that vulture congregated from different localities during the great migration. The fact that in as high as 42% of our sightings, vultures were anxiously watching wild animals around signifies the inherent efforts made by these birds in pursuit of their food i.e. the migratory wild animals. Yet still, a good proportion (18%) of these birds were actually sighted scavenging on dead wild animals. However, 28% of the sightings recorded no wild herbivores in vultures' vicinity; in these specific cases, the vultures were actually relaxing, nesting or flying on transit from one locality to another.

In conclusion, this study has recorded a total of 541 vultures of which AWBV and RGV were the most frequently encountered than HV and LFV. Intriguingly, PNV was the least while WHV, BV and EV were not sighted at all. Distribution of vultures significantly matched with presence of wildebeest and zebra than buffaloes. This study has given a snapshot of the population status of vultures in the Tanzanian part of the Serengeti-Mara ecosystem and provides insights to enhance their conservation. More extensive and detailed studies on vultures in the Serengeti ecosystem and Tanzania at large are needed to ascertain the status of vultures and facilitate wildlife management authorities to appropriately plan for sustainable conservation of these birds of prey that play a unique ecological role in their ecosystems. Establishment of an effective and long-term vulture-monitoring programme in the Serengeti ecosystem and Tanzania is justifiable and this is the time to establish the programme.

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VULTURE MONITORING PROGRAM IN SOUTHERN TANZANIA

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ABSTRACT

African vultures have declined dramatically in recent years, mostly due to poisoning. In many cases, vulture declines have occurred over short time periods and population monitoring is thus critical for vulture conservation. Southern Tanzania has potential to be an important area for vultures, but prior to 2013, no systematic surveys had been done. Beginning in 2013, North Carolina Zoo and the Wildlife Conservation Society in partnership with TANAPA began conducting roadside counts of vultures in Ruaha and Katavi National Parks, which were continued in the dry season in 2014. In 2015, surveys were conducted in both dry and wet seasons. Preliminary results suggest that the vulture population is stable and that numbers are comparable to other parts of East Africa. However, interviews with rangers and other key stakeholders demonstrate that there are several potential threats, including poisoning. Given large range sizes, WCS and NC Zoo are using satellite telemetry to understand vulture movement and ranging patterns in Southern Tanzania to inform the surveys being conducted. Our goal is to establish a long-term population monitoring program for African vultures in Ruaha and Katavi National Parks. Because ecology and conservation needs of vultures overlap closely with other species, on-going monitoring of vultures will be important for assessing the health of these ecosystems, and many other species, including carnivores and elephants, which inhabit them.

Key words: *Gyps africanus*, Katavi, poisoning, Ruaha, telemetry

INTRODUCTION

Vultures are currently the fastest declining group of birds globally (Ogada et al. 2015). Of the nine vulture species found in Africa, four are Critically Endangered and three are Endangered (IUCN Red List, 2015). Declines in avian scavengers have been noted throughout Africa, most recently in East Africa (Anderson and Mundy, 2001; Thiollay 2001, 2006a, b, 2007; Virani et al., 2011). In East Africa, declines have been severe (Ogada and Keesing, 2010; Virani et al., 2011), and poisoned carrion is likely to be the primary cause (Kendall and Virani, 2012). While there are multiple sources of poisoning incidents, the primary reason for poisoning carcasses seems to be retaliation against livestock predation by lions and hyenas, which threatens predators as well. In addition, several instances of poachers poisoning elephant and rhino carcasses have been recorded in the region. In these cases, the presumed motivation for poisoning is to intentionally reduce vulture populations, because the birds can help rangers find poached animal carcasses. Carbofuran pesticides appear to be widely used for this purpose and efforts to ban these pesticides have been largely unsuccessful (Otieno et al., 2010).

A recent workshop in Spain on vulture poisoning issues in Africa highlighted Tanzania as a current gap country in our knowledge of vulture status and population trends, and suggested the need for systematic monitoring and documentation of poisoning incidents throughout East Africa. In addition, given dramatic declines documented for vultures in Kenya and lack of overlap between Kenyan and southern Tanzanian vulture populations based on movement studies from Masai Mara National Reserve (Kendall et al. 2014), southern Tanzania may represent a relative stronghold for several vulture species. However, other than records on distribution collected for the Tanzania Bird Atlas, there is currently little information on vultures in Tanzania. Tanzania was also identified as an area likely to be important for vultures but in need of further study during a Pan-African Vulture Summit in 2012.

Soap of the Savanna

Vultures are important providers of ecosystem services such as disease control (Sekercioglu et al., 2004; Markandya et al., 2008; Ogada et al., 2012). Scavengers play a critical role in decomposition and disease control, and loss of vultures can have huge effects on the environment and in some cases, lead to major economic losses as well. Loss of vultures in India is estimated to have caused nearly $34 billion in damages (Markandya et al., 2008), with the vulture declines leading to an increase in feral dog populations which precipitated rabies outbreaks in dogs and humans. In addition to healthcare costs, loss of vultures in Africa could have important implications for the tourism industry given the likely increase in rotting carcasses that would arise from their demise becoming an unpleasant nuisance to tourists.

Indicators of ecosystem health

Vultures can also be important indicators of poaching activity as they are attracted to large carcasses, such as those of poached elephant and rhino, two species heavily impacted by wildlife trafficking. They may also provide early warning systems of poaching pressure for other species, such as buffalo, where carcasses are found in increasing frequency. In addition, because vulture populations are likely to be more sensitive to poisoning than lions, they may prove to be important indicators of conservation success when it comes to mitigating human-predator conflicts. Due to their wide-ranging behaviors and dependence on high wildlife density, vultures are key indicators of ecosystem health at a landscape scale. Vulture conservation thus has important ecological and economic ramifications and merits further attention in Tanzania.

Studies of vulture movement

Vultures are the only obligate scavenging vertebrates (DeVault et al., 2003). Because of their unique ecology, vultures must travel large distances in search of carrion, a disparate and ephemeral food source. Based on surveys from Kenya (Kendall and Virani, 2012; Kendall et al., 2014) and South Africa (Phipps et al., 2013), it is known that vultures can range over 100,000 km^2 in a single year, an area much larger than Ruaha and Katavi National Parks combined. During a study of vulture movement in Kenya in 2010 (Kendall and Virani, 2012), it was possible to establish that poisoning incidents could be causing annual mortality of some vulture species of up to 33%. This understanding of the high rate of mortality being experienced by vultures in Kenya as well as survey data from across the African continent led to the eventual up-listing of three vulture species – white-backed vultures *Gyps africanus*, Ruppell's vultures *Gyps rueppellii*, and hooded vultures *Necrosyrtes monachus* – from Least Concern to Endangered on the IUCN Red List. Further up-listing in 2015 means these birds are now Critically Endangered. Use of telemetry also allowed for careful pinpointing of *where* poisoning was occurring, allowing local law enforcement to follow up on poisoning incidents in Kenya and in Serengeti National Park, Tanzania.

Southern Tanzania Vulture Monitoring Program

Understanding the population range of vultures in Southern Tanzania will be critical for their conservation in the long term. Satellite telemetry is an important tool for vulture conservation that can be used to inform survey efforts, establish relevant population ranges or neighborhoods, discover important breeding sites, and determine principle mortality causes and rates. Because vultures range widely, it is impossible to survey an entire population. However without knowing where vultures are concentrated at different times of year, findings from surveys can be difficult to interpret. Studies of vulture movement are thus critical to understanding their ecological needs and for protecting these species.

In 2013, WCS and vulture expert, Dr Corinne Kendall (North Carolina Zoo [NCZ], US) conducted preliminary vulture surveys in Ruaha and Katavi National Parks in an effort to fill the known knowledge gap in this part of Tanzania. Vulture populations were found to be high, and current threats appeared to be low, further supporting the idea that this is an important area for vulture conservation. A monitoring program was initiated as a collaboration between WCS, NCZ and TANAPA, using both 1) regular, systematic road surveys to measure abundance, and 2) satellite telemetry to inform survey efforts, assess the population range of vultures, and provide insights on mortality causes and rates. Data from the monitoring program also aims to contribute to nest identification and provide information on the breeding status of vultures, as well as to inform research about vulture foraging behavior and habitat use in the region. The rest of this paper presents the findings from three years of road survey data and preliminary results from satellite telemetry work initiated in 2015.

METHODS

Habitats of Ruaha and Katavi National Parks

Katavi and Ruaha National Parks are the two largest protected areas in Southern Tanzania and sit approximately 300 kms apart (Figure 1). Katavi National Park is 4,471 km^2 and Ruaha National Park is 20,226 km^2. Katavi National Park is primarily composed of Miombo woodland though there are several open areas around swamps and seasonal lakes such as Lake Katavi and Chada. Ruaha National Park is composed of mixed forest and grassland areas with high wildlife density, particularly of elephants. Both parks are surrounded by several Wildlife Management Areas, which are intended to act as buffers for the parks against human encroachment. In addition, there are several game reserves neighboring each park; Rungwa, Kizigo and Muhesi Game Reserves adjacent to Ruaha National Park, and Rukwa, Lukwati and Luafi Game Reserves adjacent to Katavi National Park. All these game reserves extend the ecosystems of the parks and provide further habitat for wildlife. The large size of these protected areas and the substantial wildlife populations make them suitable habitat for vultures.

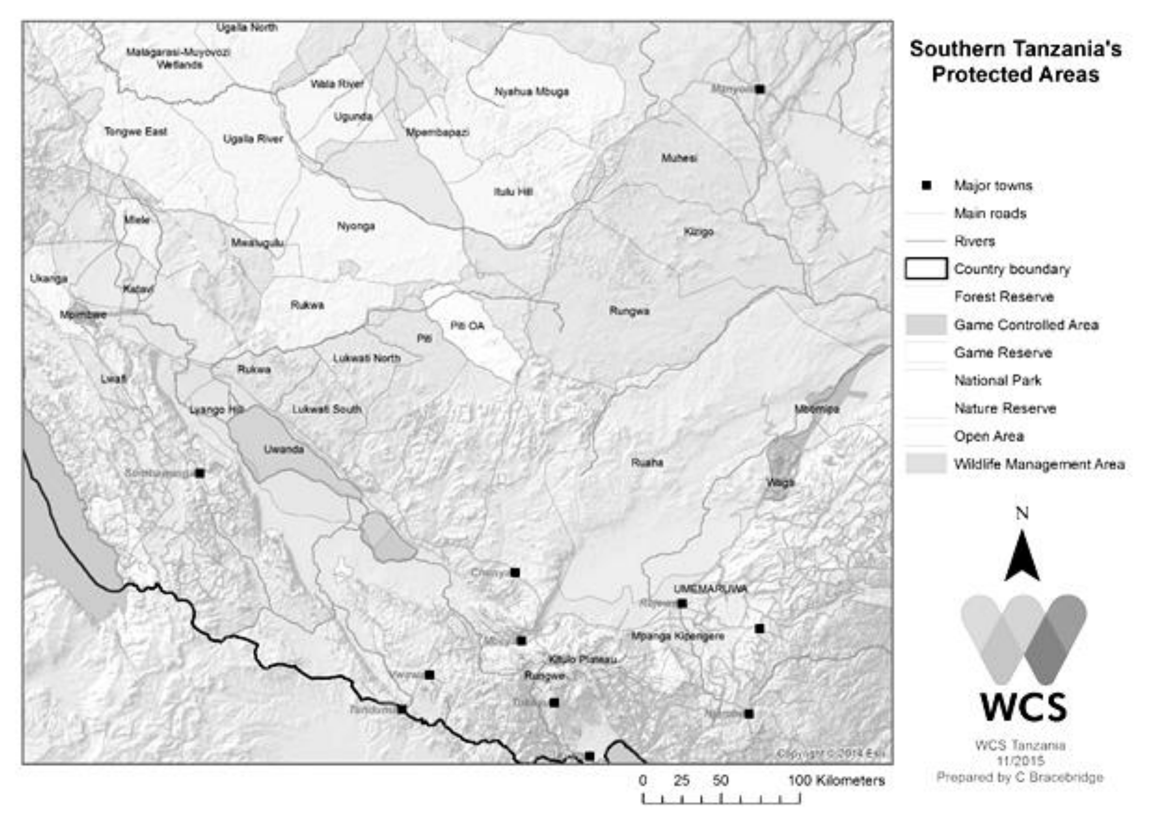

Figure 1. Map of the Southern Tanzanian landscape, showing the main protected areas, including Ruaha and Katavi National Parks

Roadside counts

Vulture (hooded vulture, lappet-faced vulture *Torgos tracheliotos,* Ruppell's vulture, white-backed vulture and white-headed vulture *Trigonoceps occipitalis)* and scavenging raptor (bateleur *Terathopius ecaudatus* and tawny eagle *Aquila rapax*) abundance was measured using roadside transects. Flying and perched birds were counted by observers along either side of the road. Transects completed in 2013 and 2015 had 4 observers while transects completed in 2014 had 10 observers, since these transects were done as part of a ranger training. Transects were treated as lines and the distances measured with the vehicle odometer. Transects were driven along main roads and other paths, traveling at 15-50 km/hour. Data were collected in CyberTracker on Nexus tablets. Transects were chosen to represent a large diversity of habitats and maximize coverage across the park. Transects were also chosen along roads that are likely to be useable during both the wet and dry seasons. All transects were completed on days of no rain and between 9 AM and 5 PM, which are the peak activity periods for most scavenging raptors, especially vultures (Mundy et al., 1992). Transects were conducted in the dry season of

2013, 2014, and in the wet and dry season of 2015 in both Ruaha and Katavi National Parks. We conducted four transects totaling approximately 362 km in Ruaha National Park and three transects totaling approximately 232km in Katavi National Park (there is some variation in transect lengths across seasons, where wet season road conditions prevent completion of some transects). Details of these transects are provided in Figures 2 and 3.

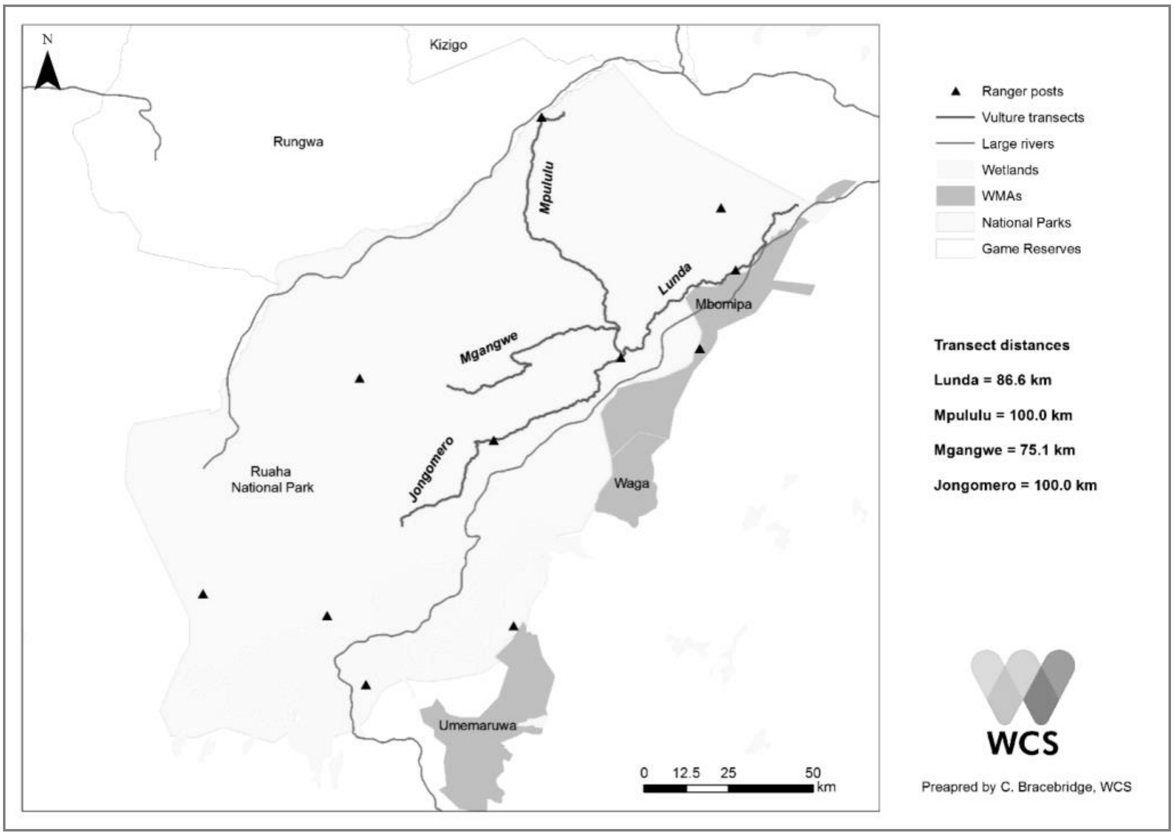

***Figure 2**: Vulture road transects conducted in Ruaha National Park*

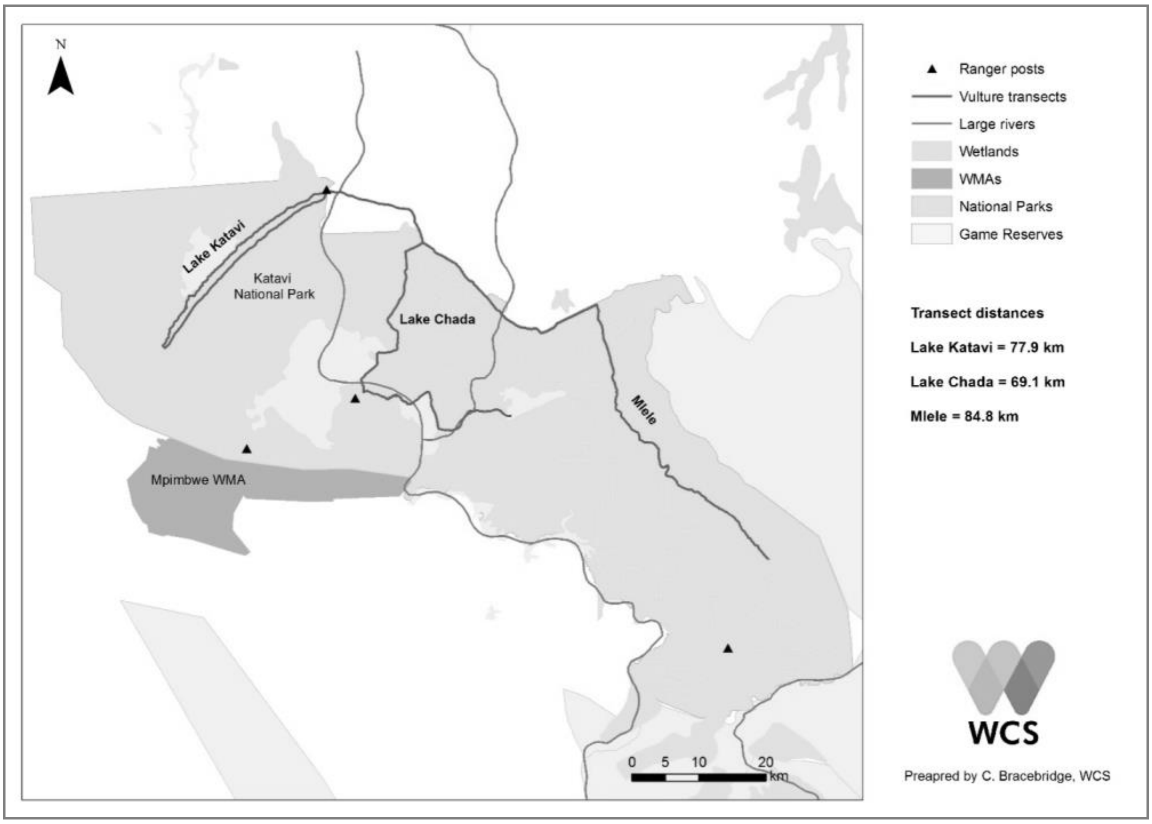

***Figure 3**: Vulture road transects conducted in Katavi National Park*

Satellite Telemetry Methods

Vultures were trapped just outside Ruaha National Park using nooses, set up as lines along carcasses (Watson and Watson, 1985). Noose on noose lines were made of coated wire cord or monofilament, and the noose line was made of parachute cord. Noose lines consisted of approximately 10 nooses, with each noose being 10-15 cm in diameter. Lines were staked into the ground using tent pegs for added stability. Grass or carrion was used to help hold the nooses upright to increase the chance of a capture. Once a bird was captured, processing took approximately 20 minutes per bird; birds' eyes were covered to reduce stress and the handler restrained both feet and head.

Two 70 gram Solar-powered ARGOS/GPS PTT tags (Microwave Telemetry, Inc., Columbia, Maryland, U.S.A.) were attached as backpacks using Teflon ribbon (Bally Ribbon Mills, Bally, Pennsylvania, U.S.A.) to white-backed vultures on September 15, 2015. Units are set to take GPS waypoints every hour from 6 AM to 7 PM and at midnight each day for a total of 15 points per day and to transmit data every three days via ARGOS satellite. Units come with a one year guarantee but could last for several years. Backpacks used to attach transmitters included a hemp stitched weak point designed to fall off within a few years, as recapture of tagged individuals is generally infeasible. This represents the first movement study of vultures tagged in Tanzania.

Telemetry data will be used to establish population ranges, discover important breeding sites, and determine principle mortality causes and rates. It is currently not known if Ruaha and Katavi National Parks represent a single vulture population and telemetry data will help to explain any trends in abundance data collected during surveys.

RESULTS

Ruaha and Katavi National Parks Survey Results

Average abundances (calculated as number of birds for a given species per 100 km) have been comparable across the three years of study (Table 1 and 2). While trends should not be extrapolated from three years of data it is useful to note that abundances have not dropped dramatically as would be expected if poisoning rates had increased significantly.

Table 1: Average number of individuals recorded per 100 km for each avian scavenger species in Ruaha National Park, Tanzania during surveys in the dry season of 2013 and 2014 and wet and dry season of 2015 (in order from most to least abundant bird in 2013)

Species	Conservation Status IUCN 2015	Ruaha NP 2013	Ruaha NP 2014	Ruaha NP 2015 Wet	Ruaha NP 2015 Dry
White-backed vulture *Gyps africanus*	Critically Endangered	45.3	50.9	17.9	33.9
Bateleur *Terathopius ecaudatus*	Near threatened	15.0	18.9	15.3	14.6
hooded vulture *Necrosyrtes monachus*	Critically Endangered	9.7	4.8	1.5	5.5
tawny eagle *Aquila rapax*	Least concern	8.1	3.7	1.0	6.0
White-headed vulture *Trigonoceps occipitalis*	Critically Endangered	4.1	2.3	2.8	3.9
lappet-faced vulture *Torgos tracheliotos*	Endangered	3.5	2.8	2.8	5.6
Ruppell's vulture *Gyps rueppellii*	Critically Endangered	0.0	0.0	0.0	0.0

Across all three years, white-backed vultures were the most common scavenging raptor, followed by bateleurs (Table 1 and 2). In Katavi National Park, white-backed vulture encounter rates were considerably higher in 2015 than in previous years, but encounter rates for all other vulture species were lower than in previous years. In Ruaha National Park, white-backed vulture encounter rates were lower than in previous years, but encounter rates for all other vulture species were higher than in previous years. Notably, white-backed vulture abundance was considerably lower in the wet season than in the dry season. We suggest that this may be caused by a home range expansion for the population, whereby vultures move out of Katavi and Ruaha

Table 2: Average number of individuals recorded per 100 km for each avian scavenger species in Katavi National Park, Tanzania during surveys in the dry season of 2013 and 2014 and wet and dry season of 2015 (in order from most to least abundant bird in 2013)

Species	Conservation Status IUCN 2015	Katavi NP 2013	Katavi NP 2014	Katavi NP 2015 Wet	Katavi NP 2015 Dry
white-backed vulture *Gyps africanus*	Critically Endangered	27.6	22.7	20.8	52.4
Bateleur *Terathopius ecaudatus*	Near threatened	19.1	7.4	12.2	10.0
tawny eagle *Aquila rapax*	Least concern	0.6	0.0	0.0	0.0
white-headed vulture *Trigonoceps occipitalis*	Critically Endangered	0.6	0.5	3.4	0.0
hooded vulture *Necrosyrtes monachus*	Critically Endangered	0.3	4.2	0.0	0.4
lappet-faced vulture *Torgos tracheliotos*	Endangered	0.0	4.8	1.0	0.9
Ruppell's vulture *Gyps rueppellii*	Critically Endangered	0.0	0.0	0.0	0.0

National Parks, during the wet season when food availability is likely to be lower. Using satellite telemetry, we will be able to better understand vulture movement patterns in the Southern Highlands of Tanzania, which will further help to inform survey efforts and findings.

Preliminary Results from Satellite Tagging

Two white-backed vultures were tagged in September 2015 (Figure 4). With only one month of data no major conclusions can be made at this time. However it appears that one of the tagged vultures has a nest and is breeding while the other is not, which should make for an interesting comparison. Figure 5 shows the first month of movement of each bird.

***Figure 4**: White-backed vulture with transmitter attached (left) and during release (right)*

So far both birds have remained primarily within the boundary of Ruaha National Park, with some forays into Rungwa Game Reserve, north of Ruaha, for bird 151401 (red lines in Figure 5), and Lunda-Nkwabi Game Controlled Area and Pawaga-Idodi (MBOMIPA) WMA (north east of Ruaha) for bird 151400 (yellow lines in Figure 5). Bird 151400 has had a more concentrated range use, which is explained by the presence of a nest and a dependent immature bird that is regularly visited. Generally the birds have used different areas within the park, with overlap in the north-central area (Figure 5). Both vultures have traveled cumulatively over 400 km per week since being tagged. We hypothesize that the vulture's ranges will expand during the rainy season when food availability within the park begins to decline. There is potential that they will travel to other nearby protected areas such as Katavi National Park, Selous Game Reserve, and perhaps even Niassa Game Reserve in Mozambique.

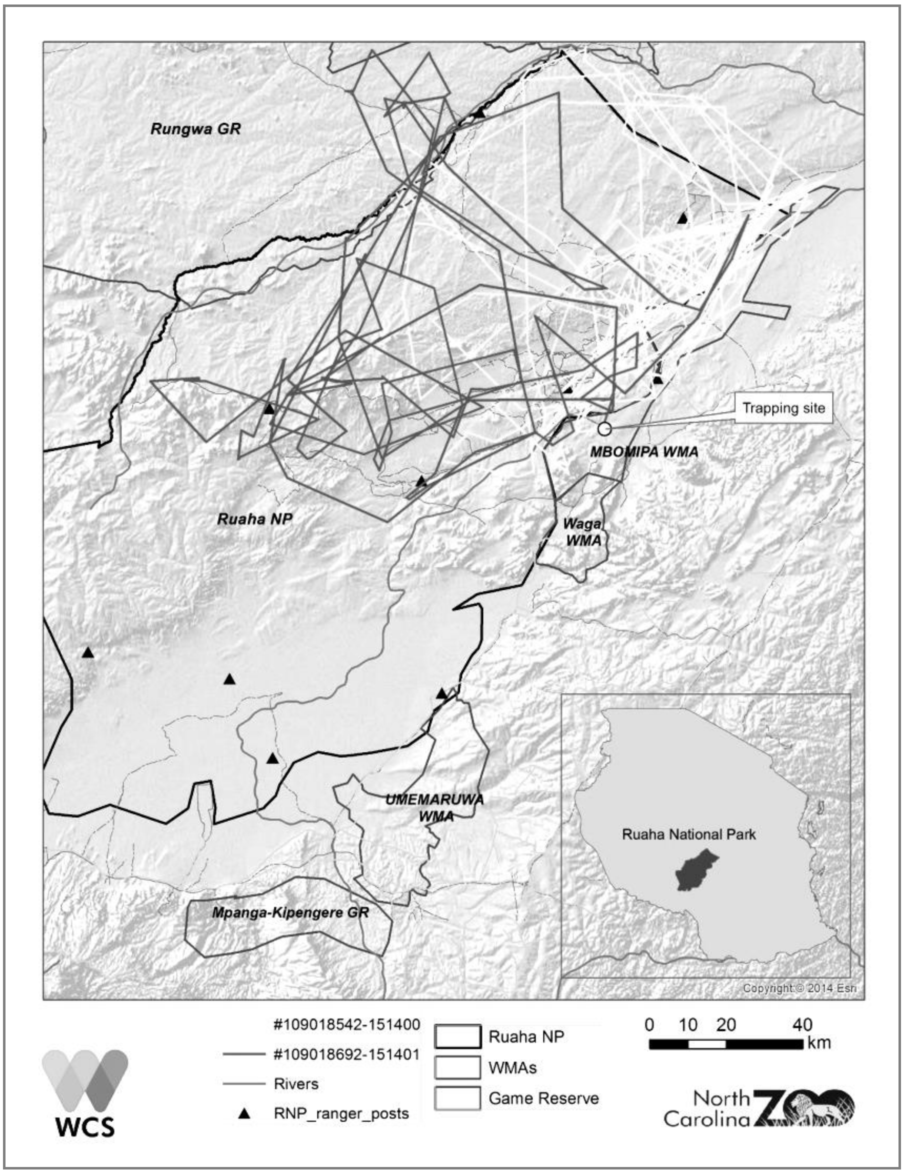

Figure 5:. *A map showing first month of movement of two satellite tagged white-backed vultures (yellow and red lines represent an individual bird)*

DISCUSSION

Abundance of vultures continues to be high in Southern Tanzania and appears to be similar to abundances found in Southern Kenya. Though we do not yet have sufficient data to analyze trends, vulture populations appear to be stable and threats to vultures in the area have likely not increased significantly since the study began in 2013. Ruaha and Katavi National Parks are clearly important ecosystems for vultures, particularly the white-backed and hooded vultures. Continued monitoring of these populations in the park is crucial, given vultures susceptibility to rapid decline should poisoning or persecution issues increase in the area.

Plans to continue vulture monitoring include repetitions of the road transects, ideally done four times per year (twice in wet season and twice in dry season), although it is likely that only two transects may be completed per year in Katavi. Information on vulture nests and vulture counts at carcasses has also been requested from rangers and guides, the latter, as part of a general initiative from various NGOs based in Ruaha, to supplement systematic data collection with contributions from citizen science. Systematic nest searches by car and by aerial surveys should be conducted to further establish the abundance and to monitor population trends. Finally, we hope to obtain funding for further telemetry work and to tag an additional eight white-backed vultures.

ACKNOWLEDGEMENTS

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AVIAN FLIGHT HEIGHTS ACROSS POWER LINES IN DAR ES SALAAM

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ABSTRACT

In recent years, Africa has experienced an increase in power generation projects. However, such development projects come with negative side effects on the environment. For example, electrocution and collision with power lines have become among the causes of mortality to populations of large terrestrial birds. Many species of birds are especially vulnerable to collision with high voltage transmission lines because of the height of these structures with respect to birds' flight altitudes. Despite the increased power lines networks, there have been very little studies on the flight heights of birds in relation to power lines. From December to February 2015, we studied flight heights of local birds as they commuted across low (LVP, 33KV) and high (HVP, 132KV) voltage power lines in Dar es Salaam. In additional to avian flight heights, we also studied their behaviours as they approached the power lines. The two power lines had different heights from the ground (13 m versus 24 m) but we targeted birds that passed between 13 ± 5 m and 24 ± 5 m recording whether a bird passed below, between or above electric cables. Using the abundance of birds that crossed the power lines, we found no preferred flight heights at LVP and HVP although all egrets passed above the cables. Changing of flight heights as birds approached power lines was recorded only for egrets whereas collision was observed for Indian House Crow and House Sparrow. We recommend that before any installation or erection of power lines, investigation on birds' routes to and from roosts and foraging sites must be conducted first. Use of underground connections and wire-marking or bird flight diverters at sensitive locations can help to reduce the risk of collision for both local and migratory flying animals especially birds.

Keywords: Collision, electrocution, flight heights, power lines, urban

INTRODUCTION

Bird flight altitudes are measured as an average height from the ground to a flying bird. Migrating and non-migrating birds show different flight heights. Migrating birds take advantage of thermals and stronger tail winds when conditions permit, allowing them to conserve energy (Newton, 2008) while staying well above power lines. In general, flight altitudes of migrating birds range from a couple hundred meters to more than 6,000 m (van Rooyen & Ledger, 1999). The height at which birds fly is an important factor in collision incidents. Most collisions occur during short distance, low altitude flights, with a high frequency of power line crossings. For non-migrating birds, and movements between stopping overs for migrating birds, flight altitude is likely to fall within the range of power line heights.

Birds' flight is a function of their feeding, mating, and roosting behaviours. These behaviours usually occur within approximately 200 m of the ground, which can expose birds to collision risk when in the proximity of power lines. Many species of birds are especially vulnerable to collision with high voltage transmission lines because of the height of these structures with respect to flight altitude, and because of their low visibility, whereas many species are potentially less vulnerable to collisions with distribution lines (Morkill & Anderson, 1991). Collectively, divers, grebes, herons, ducks, geese, swans, rails, gallinules and coots and gulls are prone to collisions where power lines occur in close proximity to water bodies or wetlands.

Electrocution and collision with power lines are considered to be a major cause of death for some avian species (Crivelli *et al.*, 1988, Smallie, 2008) such as bustards, vultures, cranes, storks and flamingos (Fiedler & Wissner, 1980). These kinds of birds have limited maneuverability in the air and have difficulty making swift, evasive actions to avoid colliding with power lines (Smallie, 2008). Electrocution can occur when a bird perches on a cross-arm and completes an electrical circuit with two or more body parts. Electrocution can also happen when the bird comes between two energized components or an energized and an earthed (also called 'grounded') component of the pole structure. Collisions, on the other hand, happen when birds fly directly into electrical lines, poles and pylons and the bird is typically killed when it collides with such obstructions and the subsequent impact with the ground, or it dies from the resulting injuries (Lehman *et al.*, 2007).

There has been increased power lines network in most cities in Africa where they are yet to use underground wiring systems, and even recently (in 2011) in Dar es Salaam a 132 KV power line was installed in a populated urban area from Ubungo to Oysterbay, while already other large power line at high heights take power to upcountry and Zanzibar (upon reaching the seashore at

Kunduchi in Dar es Salaam). Despite all these, there have been very little or no studies on the flight heights of urban birds in relation to power line network in Tanzania. Moreover, while some of the bird species may have already moved from Urban to outskirts of the cities following habitat loss to urbanization, resident birds that use mudflats, islands, river creeks for roosting and nesting have less option than to stay, and they continue moving or commuting between roosting and foraging sites. The daily movements are threatened by the infrastructure such as; tall buildings, communication towers and power lines. It is hypothesized that birds change the flight height when arriving to the power lines to avoid collision and electrocution. Thus, this study aimed at assessing the avian flight heights in relation to power lines and to investigate the responses (behaviours) of birds while crossing the power lines.

METHODS

The study was conducted in Dar es Salaam, a region covering a total area of 1, 800 sq.km, of which landmass is 1, 350 sq.km. It is Tanzania's leading industrial region and a financial capital, located on the western shores of the Indian Ocean. According to 2012 national population census, it is home to about 4.3 million people. There are many small islands and estuaries that provide good roosting sites for many medium to large birds, and is listed as an Important Bird Area (Baker & Baker 2002). In recent years, infrastructure networks such as raising buildings, communication towers, and electric networks have increased dramatically. Dar es Salaam has a complex power line network in Tanzania.

The study was conducted in three different sites along the Ubungo-Mwenge power lines network (Ubungo, Mlimani city and Mwenge), with high voltage power line (HVP) of 132KV, with a height of 24 m, and low voltage power lines (LVP) of 33 KV with a height of 13 m. Where on each power line type, three observation stations were selected after preliminary visits, priority were given to areas where many birds cross to and from roosting and or foraging sites. Each selected observation points was surveyed three times in the evening hours from 17h30 to 18h30. The study was conducted from December 2014 to February 2015. Different bird species crossing power lines were recorded, the number of individuals, and a note was taken to whether birds cross the power line at below (to -5 m), between or above (to +5 m) the electric cables. We also recorded avian behaviours mainly changing flight altitude, perching on the poles or on the wires, isolation from flock, and change of direction when approaching or while crossing power lines.

Data analyses

Data were tested for normality by using Shapiro Wilk Test before being subjected to statistical analysis to test for significance differences for the means. Non-parametric, Kruskal-Wallis, statistical test was used to compare the flight heights within each voltage power line (below, between and above) while avian flight heights between HVP and LVP was tested by using Mann-Whitney, *U*-test. Behaviours (isolation from the flock, collision, changing the flight height, change of direction, perching, etc.) were recorded and their frequency was determined and depending on the frequency; because of limited samples, descriptive analysis was used. All data were analysed by using PAST and SYSTAT software.

RESULTS

Species composition

Overall, we recorded 11 bird species; IHC (*Corvus splendens*), House sparrow (*Passer domesticus*), Little egret (*Egretta garzetta*), Cattle egret *(Bubulcus ibis*), Goliath heron (*Ardea goriath*), Hamerkop (*Scopus umbretta*), Black kite (*Milvus migrans*), Little swift (*Apus affinis*), Sacred ibis (*Threskiornis aethiopicus*), Black-headed heron (*Ardea melanocephala*), and Wire-tailed swallow (*Hirundo rustica*). With exception of sacred ibis, the rest were also recorded at Ubungo. Only two bird species, IHC and House sparrow, were recorded at Mlimani City while five bird species namely IHC, House sparrow, Little egret, Cattle egret and Sacred ibis were recorded at Mwenge. IHC was abundant at all sites and they crossed both LVP and HVP. The other common species were House sparrow, Little egret, Wire- tailed swallow and Cattle egret. The rest of the species were observed crossing only HVP (Table 1). Two species (IHC and House sparrow) among all, crossed the power line at all altitudes (i.e. below, between and above the cables), the rest of the species were passing above the cables.

Table 1: Mean and Standard deviation (Mean±SD) of the number of individuals of each species at different study locations along LVP and HVP

Species	Ubungo		Mlimani City		Mwenge	
	LVP	HVP	LVP	HVP	LVP	HVP
IHC	608.7±15.0	399.3±114.0	104.7±20.5	144.3±95.2	335.7±28.8	362.3±134.5
Little egret	31±11.53	47.7±32.1	-	-	28.7±6.03	20.3±10.6
House sparrow	32±3.0	35.3±52.6	46.3±12.22	14.7±13.2	46.7±9.3	39±21.1
Cattle egret	-	2±1.73	-	-	-	-
Goliath heron	-	1	-	-	-	-
Hamerkop	-	1	-	-	-	-
Black kite	-	1	-	-	-	-
Little swift	-	1	-	-	-	-
Black -headed heron	-	1	-	1	-	-
Sacred ibis	-	-	-	1	-	-
Wire -tailed swallow	-	8	-	-	-	-

The flight heights within HVP

There were variations between the flight heights within HVP (Kruskal Wallis Test, $H=18.07$, $P<0.001$). Many birds were passing below and above the power lines than between the electric wires (Figure 1). Pairwise Mann-Whitney comparisons test showed a significant difference in flight height preference for above and between cables ($P<0.001$), below and between ($P=0.003$) but there was no significant difference for below and above ($P= 0.199$).

Flight heights within LVP

Preference for flight heights within LVP varied significantly ($H=30.53$, $P<0.001$). Many birds were passing above than between or below the power lines (Figure 2). Pairwise Mann-Whitney comparison test show a significant difference for above and between cables ($P=0.004$), below and above ($P<0.001$) but there was no significant difference for below and between cables ($P=0.08543$).

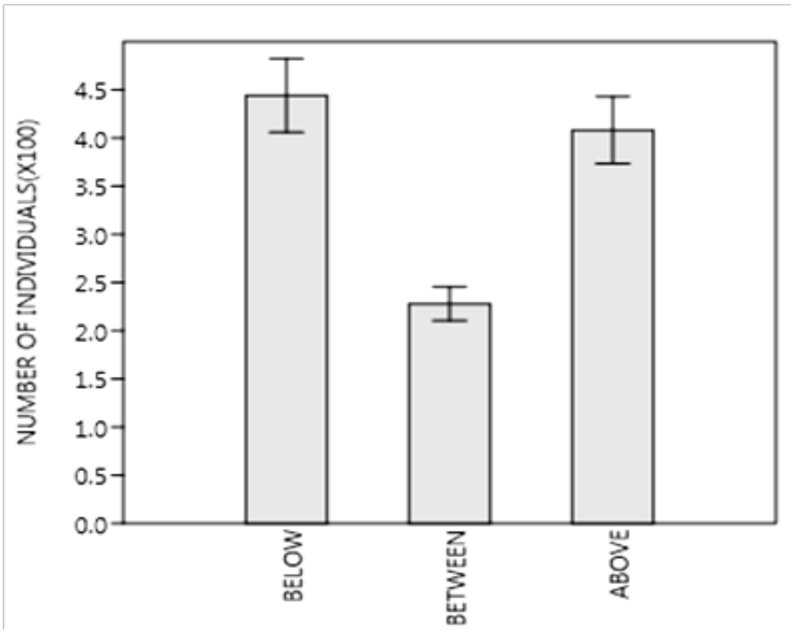

Figure 1:. *Avian flight height preferences at HVP (132 KV)*

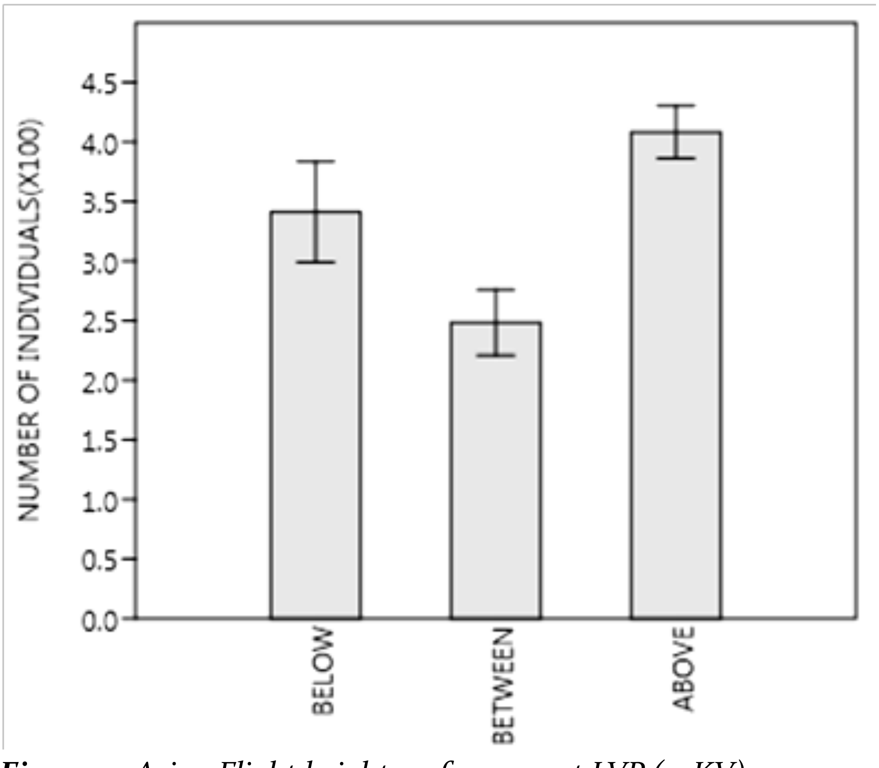

Figure 2: *Avian Flight height preferences at LVP (33KV)*

The flight heights between HVP and LVP power lines

There were no variations between the avian flight heights preferences within HVP and LVP (Mann-Whitney U-test, U=2.9221x10^{-5}, P=0.647) (Figure 3). This indicates that LVP and HVP are within the observed flight heights of the local birds.

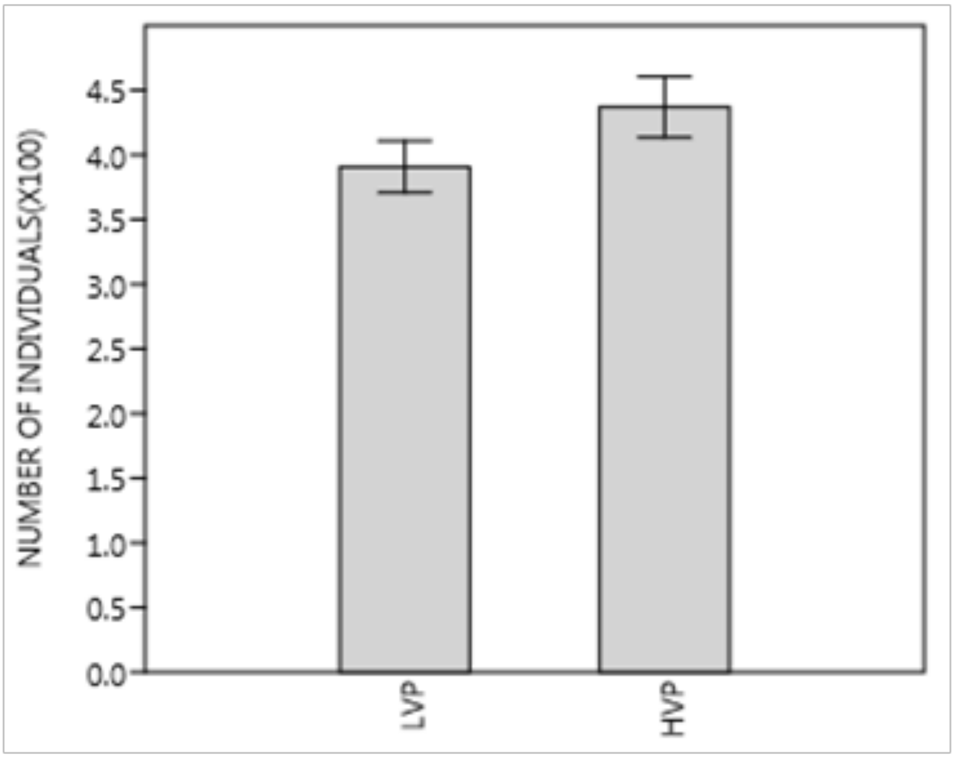

Figure 3: *Flight heights of local birds at HVP (132KV) and LVP (33KV)*

Power lines and bird behaviours

All species passed above the power lines with exception of IHC and House sparrow which passed in all levels (below, between and above) of the power lines. Collision was observed for IHC and House sparrows while crossing LVP. The change of flight heights were observed for Little and Cattle egrets while crossing HVP. Also perching on the wires of LVP was observed on IHC and House sparrow (Table 2). Birds did not perch on wires on HVP.

DISCUSSION

Few species were observed crossing power lines during the study. This is because in urban areas of Dar es Salaam few species roost communally. Egrets, house crows, house sparrow commute daily from roosting sites to foraging areas which are mostly located outside the Central Business District (CBD). Solitary and small family living species usually disperse in areas near their roosting sites for feeding.

Because resident urban species move shorter distances between roosting and foraging sites, they move at lower altitude compared to long-distance migrants, and thus are vulnerable to collision with power lines and other tall infrastructures within urban areas. The power lines height of both LVP and HVP in Dar es Salaam fall within the local avian flight heights suggesting high risk of collision. These power lines heights are standard throughout the region, thus most resident birds are affected in the same ways, and if such infrastructures are constructed or erected within the migratory routes of long distance migrants may pose serious threats especially at stopping over sites. However, as a strategy to avoid collision and electrocution, it seems that some species avoid collision by changing altitude or flight heights when approaching power lines especially medium and large birds such as little egrets.

Table 2. The frequencies (%) of the impacts of power lines on different birds while crossing HVP and LVP

Impacts of power lines on avian behaviors	Species	Frequency (%)	
		HVP	LVP
Isolation from the flock	Indian house crow	0.5	5.3
Perching on the pole	Indian house crow	1.7	13.3
Perching on the pole	Black kite	0.24	0
Perching on the wires	House sparrow	0	4
Perching on the wires	Indian house crow	0	40
Raising the flight heights	Little egret	94.4	0
Raising the flight heights	Cattle egret	1.5	0
Collision	Indian house crow	0	16
Collision	House sparrow	0	6.7
Change of direction	Indian house crow	1.7	9.3
Change of direction	House sparrow	0	4

This avoidance behavior is not known if it happens when birds meet objects while in flight or is by learning? If it is by learning, how long does it take to learn when a new power line is installed and what impact a new power line causes before birds can learn? This can be established by monitoring collision and electrocution when a new power line is installed, but bird carcasses may not stay longer (Pallett, 2014), they are removed by human during cleanliness and by dogs, cats and crows.

Large birds have poor maneuverability which could lead to collision if they attempt to pass through or between electric wires at HVP unlike IHC and House sparrow which cross between power lines. Conversely, in other studies using behaviours categories similar to the one used in this study, birds reacted most commonly by raising the flight heights (James & Haak, 1979, Morkill & Anderson, 1991). However, it is mostly likely that our study birds have learn the presence of power lines through experiences and may be moving at small speed unlike long-distance migrating birds which are constraints with time and stopping over sites. Birds that approach power lines at the middle or between electric wires, change behaviours more often than those approaching either well above or well below the lines (Morkill & Anderson, 1991).

IHC and House sparrow were seen perching on cables at LVP this is because a bird has the same charge as the power lines, and when it sits on it, it has more resistance than the lines themselves, but this cannot help for HVP.

CONCLUSION AND RECOMMENDATION

Birds changed flight height when arriving near the power lines to avoid collision, moreover, IHC and House sparrow passed through the power lines. This study confirms that power line networks in urban areas interfere with movements of local birds, a subject which has been ignored by both wildlife experts and electric engineers or project developers. Thus the study recommends that, research must be conducted before the installation of power lines, in order to identify sensitive areas such as daily commuting and migratory routes of local and migratory birds, respectively. Resident birds that roost communally use specific routes to and from the foraging sites, such routes shouldn't be interrupted by infrastructures such as power lines. Migratory birds also when moving within or from foraging stopping-overs are likely to be affected by power lines. Such sensitive areas should be identified before such infrastructures are erected. In order to reduce the collision rate, wire-marking or flight bird diverters must be used to increase the visibility of the wires, which alerts birds to the presence of power lines and provide them with more time to avoid the collision.

ACKNOWLEDGEMENTS

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COMMON AND RARE BIRD SPECIES IN THE SOUTHERN PART OF SAADANI NATIONAL PARK

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ABSTRACT

Saadani National Park (SANAPA), located along the eastern coastline of Tanzania, is the closest wildlife sanctuary from the business capital, Dar es Salaam. Although the populations of game animals do not attract many tourists at the moment, it has a potential of becoming a bird watching paradise. Nonetheless, very little ornithological observations have been documented. This study, based mainly on the species encounter rates, provides indices for 'common' and 'rare' bird species in the southern part of SANAPA. Between June and July (touristic peak season for eastern Africa parks) 2013, timed species counts (TSCs), mist netting, total counts and opportunistic observations were used to study the avian diversity in woodland-bushed grassland, riverine forests, and mangrove-saltpans habitat. In total, 97 species were recorded from 26 TSCs, among these 76 were sighted in woodland-bushed grassland and 47 from mangrove-saltpans habitat. About 50% of all recorded birds were common (with >1.0 mean score, MS) at mangrove-saltpans while 4 species were very rare (0.8<, MS) at this site. Moreover, in the woodland-bushed grassland, 19 species were common and three were recorded only once. Twenty two species were added from opportunistic observations and mist netting. A total count at salt works on 3rd and 18th July estimated an average of 400 greater and 500 lesser flamingos. Black-winged stilts were also abundant (350 birds) at the saltpans. Observations in this study amounts to over 30% of total bird species within SANAPA. The study provides information on site-specific species commonness (likelihood of encounter) which is crucial for avi-tourism promotion and park management.

Keywords: Birding, bird mean scores, dry season, Saadani, salt pan

INTRODUCTION

The eastern Africa coastline habitats are facing threats from human population growth from internal immigrants and natural population growth which results into high demands for investments. In Tanzania, urbanization along coastline, from Tanga, Bagamoyo, Dar es Salaam to Mtwara town, is growing at higher rate than inland and as a result very little natural habitat remains outside the protected areas. However, the growing human population and economies along the coastline towns with limited recreation parks offers opportunities for holiday and weekend trips to natural habitats. For example, Dar es Salaam will register the fastest growth in the number of households (8.7% of Tanzania population will be living in Dar es Salaam by 2025) in the emerging middle class ($5,000 - $20,000 per year in revenue) by 2030 (World Bank, 2012; The Africa Report, 2013). This has a potential of increasing or stimulating domestic tourism especially for attractions in close proximity such as Saadani National Park (SANAPA) which is about 100 km from Tanzania's financial capital, Dar es Salaam. Dar es Salaam is also is home to diplomats and the leading tourists' entry point for Tanzania. Studies on the tourists' choice have indicated that distance could affect preference of destinations (Nicolau & Más, 2006; Nicolau, 2008). Travel from one's place of usual residence to destination entails physical, temporal and monetary costs (Taylor & Knudson, 1976).

SANAPA is among the few protected areas along the eastern Africa coastline, others include the marine parks and reserves. Saadani is the only fully protected area in Tanzania with a mixture of terrestrial, littoral and marine resources (Baldus *et al.,* 2007; Marttila, 2011), this complex environment is home for many life forms, and the reason why it has a potential of attracting many visitors for wildlife viewing. Conversely, biodiversity or species richness contributes to nature-based tourism by enhancing attractiveness of an area to tourists. For example, a study by Naidoo and Adamowicz (2005) in Uganda, reported that as the number of bird species increased, tourists demonstrated an increase in willingness to visit a protected area. With over 300 bird species (Marttila, 2011), Saadani has a potential of becoming a birdwatching paradise given the growing avitourism industry in tropical region (Motsumi *et al.,* 2003). Furthermore, avian diversity, which has not been intensively studied (Marttila, 2011), in combination with other attractions and uniqueness could be used in the park tourism marketing strategy. Available information on SANAPA birdlife (Baldus *et al.,* 2007; Marttila, 2011) gives only the checklist and accounts on few species. However, for proper planning of birding trips, information on the status of avian species diversity and likelihood of encounter is crucial.

In this article, I provide an assessment of bird species commonness (likelihood of encounter) in the southern part of SANAPA during the dry season, the peak of touristic season in eastern Africa parks.

METHODS

Study area and sites

SANAPA lies along the Tanzania coastline, about 100 km North of Dar es Salaam, and it is 50 km from Bagamoyo town. Gazetted in 2005, the park has five principal habitats; savanna-grassland mosaic, coastal lowland forest, riverine forest, mangrove forest and sea shore. It has a maximum length of 69 km from south to north (Marttila, 2007). The park has two main seasons; dry season from July to September and wet season from November to May with less rain in December to February.

The study was conducted in the southern part of the park, mostly south of Mvave River outside of Zaraninge Forest (Figure 1). The areas covered were wooded and bushed grassland (this area has a savanna-grassland mosaic with a varied habitat complexity of short grasslands, wooded grassland and thickets, *hereafter,* termed as woodland-bushed grassland), riverine forests, and mangrove-saltpan habitats. Major concentration was in areas between sea salt village and Wami estuary, Kinyonga campsite and Wami gate, Matipwili village and Wami gate, and park tourism office/Saadani Village and Mvave gate (Figure 1). The study was conducted between 20th June and 20th July 2013.

Survey Methods

Survey methods used include; Timed Species Count (TSC), total counts (TC), mistnetting and opportunistic observations.

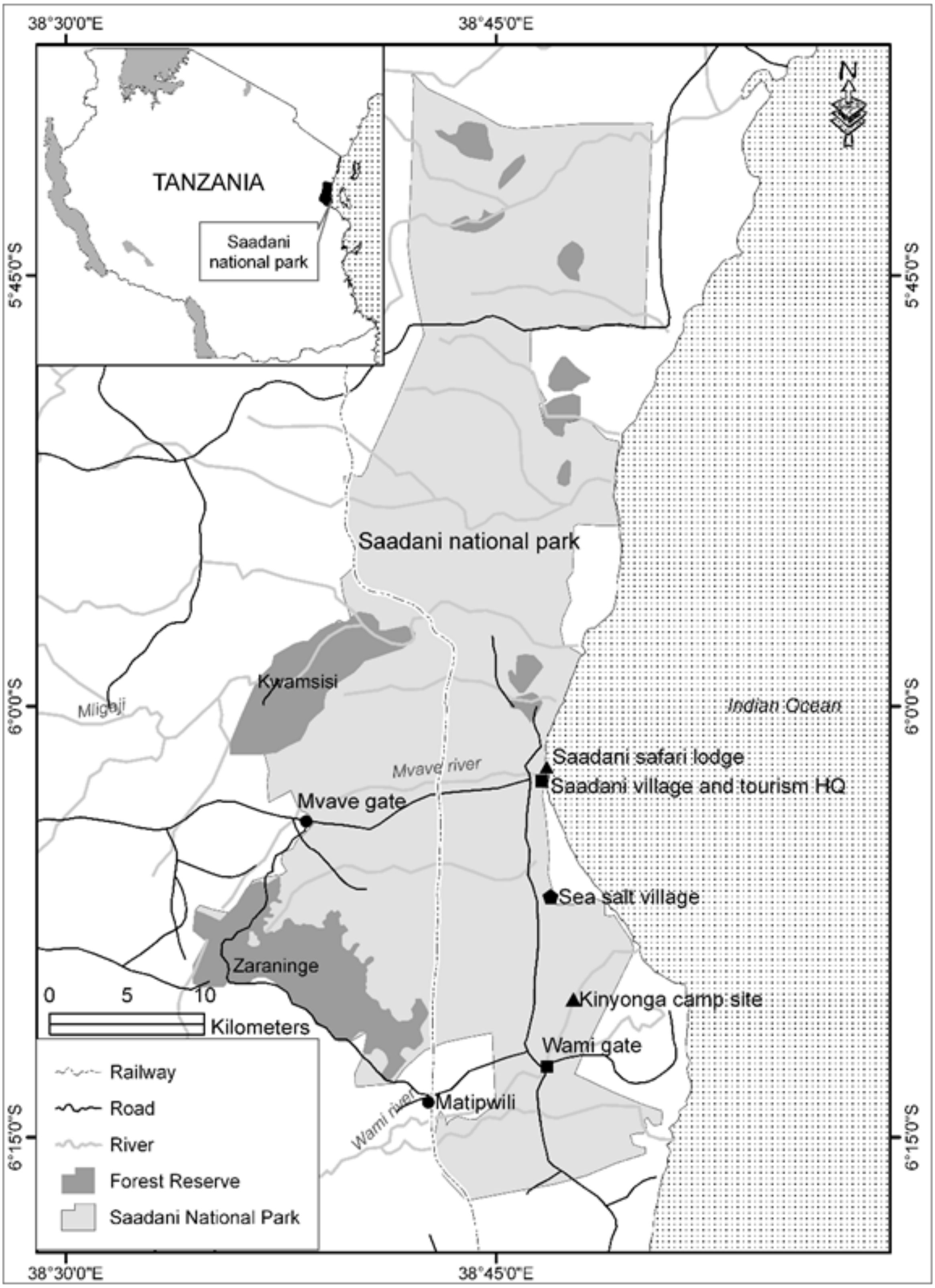

***Figure 1**: Map of Saadani National Park showing areas referred in the text*

Timed Species Counts

Timed species counts (TSCs) were carried out over a fixed period 1 h divided into shorter periods of 10 min each (Pomeroy, 1992; Bennun & Howell, 2002).

The TSCs were separated by a break of 10 min. A species seen or heard in the first 10 min received a 'score' or 'weight' of 6, while a species first recorded in the second 10 min period scored 5 and so on. Park road and trail networks were used, concentrating on places were bird activity (e.g. foraging) was greater. The survey consisted of 26 TSCs, 13 in Mangrove-Saltpan habitat and 13 in woodland-bushed grassland. This method is recommended for woodland and bush habitats (Pomeroy & Tengecho, 1986), in additional to producing a checklist; it also provides a reasonable measure of relative abundance (Bibby *et al.,* 2000). Most of the TSCs were carried out in the morning.

Total counts

Total count method as described by Norton-Griffiths (1978) was used for congregatory waterbirds in the saltpans particularly the flamingos and stilts. Counts were made using binoculars and a telescope while standing on the central dykes of the saltpans.

Mist nets

Mist nets were set along riverine habitats of Wami River at Kinyonga Campsite and Wami gate. Six nets (three at each site) were set for three consecutive days at both sites. Nets (12 x 2.5 m) were opened from 0730 to 1930 hrs, and checked every 30 to 45 minutes. To assess recaptures, birds were banded with either colour or East Africa metal rings.

Opportunistic observations

Opportunistic observations were carried out targeting species that are very hard to observe with TSCs and do not come down to mistnets. Other common animals, especially game animals, were also recorded using this method.

Data analysis

Data for TSC were analysed for species relative abundances which is expressed in mean scores (MS), and species were then ranked for commonness (likelihood of encounter) using the MS values. TSC indices were used to categorize species into 'common' and 'rare'; common = MS≥0.1, rare = MS<0.1. Because data were not normally distributed, Mann-Whitney U-test (PAST software) was used to compare MS between Woodland-bushed grassland, and Mangrove-Saltpan habitats. Shannon-Wiener Index of Diversity was used for bird species diversities in the study habitats and were tested using special *t*-test (Krebs, 1999).

RESULTS

In total, 119 species were recorded, 97 from 26 TSCs while 22 species were added from opportunistic observations and mist netting. Although equal efforts (13 TSCs in each) were assigned in each habitat, Mangrove-Saltpan had fewer species (47 species) than Woodland-bushed grassland (76 species) with 21 species exclusively found in Mangrove-Saltpan habitats including flamingos (Table 1). The comparison of the total MS showed a significant difference ($U' = 1309$, $n_1 = 76$, $n_2 = 47$, $p = 0.013$) between the two habitats being higher in Woodland-bushed grassland. However, proportion wise; Woodland-bushed grassland had many 'rare' (73%, with MS<0.1) bird species than Mangrove-Saltpan (53%, MS<0.1). Species with MS>1.00 are locally common on a site with highest probability of being seen within one hour of observation.

Mist netting at two riverine sites, Kinyonga Campsite and Gama Bridge/Mkurunge Gate, produced 28 species; *yellow-breasted apalis *Apalis flavida*, olive sunbird, Zanzibar sombre

Table 1: TSC indices (Species Mean Scores) for species recorded in the Southern part of Saadani National Park in dry season of 2013. Zero mean score indicates that a species was not recorded in that particular site. The higher the mean scores the locally abundant the species is.

Species	Species Mean Scores (MS) for Woodland-Bushed grassland	Species Mean Scores (MS) for Mangrove-Saltpan
Zanzibar sombre greenbul *Andropadus importunes*	3.462	2.769
Red-eyed dove *Streptopelia semitorquata*	3.231	2.385
Collared sunbird *Hedydipna collaris*	2.154	1.385
Emerald spotted-wood dove *Turtur chalcospilos*	1.923	1.154
Speckled mousebird *Colius striatus*	1.538	1.846
Ring-necked dove *Streptopelia capicola*	1.462	1.769
White-browed coucal *Centropus superciliosus*	1.462	0
Village indigobird *Vidua chalybeate*	1.462	0
Common bulbul *Pycnonotus barbatus*	1.385	2.308
Red-cheeked cordonbleu *Uraeginthus*	1.231	0

Species	Species Mean Scores (MS) for Woodland-Bushed grassland	Species Mean Scores (MS) for Mangrove-Saltpan
bengalus		
Rattling cisticola *Cisticola chiniana*	1.231	0
Crowned hornbill *Tockus alboterminatus*	1.231	0
Red-fronted tinkerbird *Pogoniulus pusillus*	1.000	0.538
Pin-tailed whydah *Vidua macroura*	1.000	0
Tawny-flanked prinia *Prinia subflava*	1.000	0.154
Bronze mannikin *Lonchura cucullata*	1.000	0.308
Yellow-billed stork *Mycteria ibis*	0.923	1.462
Scarlet-chested sunbird *Nectarinia senegalensis*	0.846	0.923
Hadada ibis *Bostychia hagedash*	0.846	0
White-crested helmet shrike *Prionops plumatus*	0.769	0
Northern brownbul *Phyllastrephus strepitans*	0.769	0.769
Namaqua dove *Oena capensis*	0.769	0
Little bee-eater *Merops pusillus*	0.692	2.077
Woolly-necked stork *Ciconia episcopus*	0.615	1.692
Long-tailed fiscal *Lanius cabanisi*	0.615	0
Brown-crowned tchagra *Tchagra australis*	0.615	0
Tiny cisticola *Cisticola nanus*	0.538	0.385
Black-crowned tchagra *Tchagra senegala*	0.538	0.077
Winding cisticola *Cisticola galactotes*	0.538	0
House sparrow *Passer domesticus*	0.462	0.769
Common fiscal *Lanius collaris*	0.462	0
Black-backed puffback *Dryoscopus cubla*	0.462	0
Zanzibar red bishop *Euplectes nigroventris*	0.462	0
White-fronted bee-eater *Merops bullockoides*	0.462	0
Yellow-throated longclaw *Macronyx croceus*	0.462	0
White-eared barbet *Stactolaema leucotis*	0.462	0
Eastern green tinkerbird *Pogoniulus simplex*	0.462	0
African golden weaver *Ploceus subaureus*	0.462	1.692
Tropical boubou *Laniarius aethiopicus*	0.417	1.385
Yellow-rumped tinkerbird *Pogoniulus bilineatus*	0.385	0

Species	Species Mean Scores (MS) for Woodland-Bushed grassland	Species Mean Scores (MS) for Mangrove-Saltpan
Black kite *Milvus migrans*	0.385	0.615
Bat hawk *Macheiramphus alcinus*	0.385	0
Green-backed camaroptera *Camaroptera brevicauda*	0.385	0
Hamerkop *Scopus umbretta*	0.385	0
Madagascar bee-eater *Merops superciliosus*	0.385	0
Spot-flanked barbet *Tricholaema lacrymosa*	0.385	0
Uluguru violet-backed sunbird *Anthreptes neglectus*	0.385	0
Krestchmer's longbill *Macrosphenus krestchmeri*	0.385	0
Narina trogon *Apaloderma narina*	0.385	0
Sourthern cordon bleu *Uraeginthus anglolensis*	0.385	0
Von der Decken's hornbill *Tockus deckeni*	0.308	0
Fish eagle *Haliaeetus vocifer*	0.308	0.077
Palm-nut vulture *Gypohierax angolensis*	0.308	0.077
Mosque swallow *Hirundo senegalensis*	0.308	0
African pygmy kingfisher *Ispidina picta*	0.308	0
Spectacled weaver *Ploceus ocularis*	0.308	0
Retzs helmet shrike *Prionops retzii*	0.308	0
Lesser masked weaver *Ploceus intermedius*	0.308	0
Parasitic weaver *Anomalospiza imberbis*	0.308	0
Cattle egret *Bubulcus ibis*	0.308	0.463
Olive sunbird *Nectarinia olivacea*	0.231	0
Purple-banded sunbird *Cinnyris bifasciata*	0.231	0.385
Green Wood-hopoe *Phoeniculus purpureus*	0.231	0
Gabar goshawk *Micronisus gabar*	0.231	0
Senegal plover *Vanellus lugubris*	0.231	0.385
Pied crow *Corvus albus*	0.231	0
African grey hornbill *Tockus nasutus*	0.231	0
Cardinal woodpecker *Dendropicos fuscescens*	0.231	0
White-browed robin chat *Cosssypha heuglini*	0.231	0
White-rumped swift *Apus caffer*	0.231	0

Species	Species Mean Scores (MS) for Woodland-Bushed grassland	Species Mean Scores (MS) for Mangrove-Saltpan
Red-billed firefinch *Lagonosticta senegala*	0.231	0
Eastern paradise whydah *Vidua paradisaea*	0.154	0
Village weaver *Ploceus cucullatus*	0.154	0
Plain-backed sunbird *Anthreptes reichenowi*	0.077	0
Crested flancolin *Fracolinus sephaena*	0.077	0
White-headed vulture *Trigonoceps occipitalis*	0.077	0
Lesser flamingo *Phoeniconaias minor*	0	2.308
Little egret *Egretta garzetta*	0	2.308
Lesser striped swallow *Hirundo abyssinica*	0	2.077
Pied kingfisher *Ceryle rudis*	0	1.846
Black-winged stilt *Himantopus himantopus*	0	1.462
Greater flamingo *Phoenicopterus ruber*	0	1.462
Grey heron *Ardea cinerea*	0	1.462
African pied wagtail *Motacilla aguimp*	0	1.231
Common sandpiper *Actitis hypoleucos*	0	1.154
Wire-tailed swallow *Hirundo smithii*	0	1.000
Tambourine dove *Turtur tympanistria*	0	1.000
Common drongo *Dicrurus adsimilis*	0	0.769
Saddle-billed stork *Ephippiorhynchus senegalensis*	0	0.769
Brown breasted barbet *Lybius melanopterus*	0	0.538
Eurasian roller *Coracias garrulous*	0	0.308
Black-winged red bishop *Euplectes hordeaceus*	0	0.231
Amethyst sunbird *Chalcomitra amethystine*	0	0.231
African open-billed stork *Anastomus lamelligerus*	0	0.154
Black-headed oriole *Oriolus larvatus*	0	0.154
Croacking cisticola *Cisticola natalensis*	0	0.154
Three-banded plover *Charadrius tricollaris*	0	0.077

greenbul, *red-capped robin-chat *Cosssypha natalensis,* *vitelline masked weaver *Ploceus velatus,* *eastern bearded scrub-robin *Cercotrichas quadrivirgata,* *sulphur-breasted bush-shrike *Malaconotus sulfureopectus,* speckled mousebird, common bulbul, *red-collared widowbird *Euplectes ardens,* *mouse-coloured sunbird *Cyanomitra veroxii,* purple-banded sunbird, tawny-flanked prinia, African pygmy kingfisher, *lesser honeyguide *indicator minor,* *red-billed quelea *quelea quelea,* red-fronted tinkerbird, tambourine dove, *red-headed quelea *Quelea erythrops,* *fan-tailed widowbird *Euplectes axillaris,* *Peter's twinspot *Hypargos niveoguttatus*, *marsh tchagra *Tchagra minuta*, *yellow-fronted canary *Serinus mozambicus,* emerald spotted wood dove, red-billed firefinch, black-crowned tchagra, spot-flanked barbet and green-backed camaroptera. Thirty nine individuals (19 species) were mistnetted at Gama Bridge while at Kinyonga 26 individuals (13 species) were caught. Shannon-Wiener Index of Diversity H' index between two sites (H' = 2.517 *Versus* H' = 2.102) differed marginally $t_{(53.37)}$ = 2.033, p = 0.047. Of the 28 species caught in mist nets, 14 species were not recorded during TSCs, starred (*) species above.

A total count at salt works on 3rd and 18th July estimated an average of 410 (400 and 420 respectively) greater and 500 (550 and 450 respectively) lesser flamingos. Black-winged stilts were also abundant (*c.*350 birds) at saltpans. Small groups of Pink backed pelicans (16-20 birds) were observed at the saltpans on 18th July 2013. Other 7 species were added during opportunistic observations; they included; Yellowbill *Ceuthmochares aereus*, Sacred ibis *Threskiornis aethiopicus*, Long-tailed cormorant *Phalacrocorax africanus*, Augur buzzard *Buteo augur*, Brown-headed parrot *Poicephalus cryptoxanthus*, Great white egret *Egretta alba* and Greater white pelican *Pelecanus onocrotalus*.

Other wildlife species recorded during this study which are likely to attract the attention of birders in the southern part of the park included: African elephant *Loxodonta Africana*, giraffe *Giraffa camelopardalis,* monitor lizard *Varanus niloticus*, common waterbuck *Kobus ellipsiprymnus*, African rocky python *Python sebae*, lion *Panthera leo*, hippopotamus *Hippopotamus amphibious*, Nile crocodile *Crocodilus niloticus*, yellow baboon *Papio cynocephalus cynocephalus*, vervet monkey *Cercopithecus aethiopicus* and warthog *Phacochoerus aethiopicus*.

DISCUSSION

Using park road and walking trail networks, mistnets and opportunistic observations, this study recorded 119 bird species in the southern part of SANAPA. About 301 bird species is reported from SANAPA (Baldus *et al.*, 2007), thus, observations from this study represent over 30% of the total bird species for this park. This study, therefore, proves that the southern part of park is very important for birdlife because less than 30% of the park size were covered which also excluded Zaraninge Forest, a part of the Bagamoyo Coastal forest Important Bird Area (Baker & Baker, 2002). Habitat mosaics (woodland, grassland, riverine, saltpans, mangrove and intertidal zones) in the southern region support diverse avian species (Baldus *et al.*, 2007; Marttila, 2011). Moreover, southern part of the Saadani Park is also important for game wildlife populations (Baldus *et al.*, 2007; Chambegga *et al.*, 2007).

The Woodland-bushed grassland had more species with lower MS because of the varied habitat complexity which provides hiding places for many species of birds. Moreover, the lower MS in this habitat could be subjected to the fact that the observers restricted themselves to the road networks and no efforts were done to search for the species in bushes far from the road network. The study assumes that birdwachers visiting the park will use park road networks because trespassing and off-road driving is discouraged. Species recorded by TSCs can easily be spotted in the open and semi-open areas of the park, whereas few of those mistnetted hide in riverine habitats and could not be easily encountered. Some of these species e.g. Eastern bearded scrub robin, Peter's twinspot, Marsh tchagra, Yellow breasted apalis, are often shy and difficult for a person on an ordinary visit to the park to see, keeping to thick vegetation cover. A visitor wanting to see such species is advised to search them in the appropriate habitats. It is also important to note that not all species can be recorded in short period of park visit; even some of the common species could go unnoticed as it was the case in this study. Temminck's courser *Cursorius temminckii*, for example, is known to be a common species in the woodland-bushed grassland within Saadani but was missed.

Morttila (2011) lists the most frequent bird species that are confined to the savanna-grassland mosaic in Saadani. In the list are the common bulbul, purple-banded sunbird, scarlet-chested sunbird, African pied wagtail, speckled mousebird and various doves, the most common being the ring-necked dove. The results of the current study support the above literature although the purple-banded sunbird had the lowest mean scores. Surprisingly, Zanzibar sombre greenbul is not mentioned in previous reports for Saadani to be among the most common species contrary to the findings of this study. This could be due to the fact that, unless, observers are familiar with its call, it could be hard to spot as it keeps on cover.

Many waterbird species were recorded in saltpan and the mangrove from the Sea-salt Ltd to Wami (Kinyonga) estuary. Saltpan provided foraging sites for flamingos, pelicans, stilts, herons, storks, egrets and small waders such as common sandpiper. Flamingos, for example, are attracted to this area because of the algae growth on the salt extraction pans (Marttila, 2011; Omari, 2013). Although Lesser flamingos are quite popular in soda lakes in northern part of Tanzania, Saadani in particular the salt pan is the single most significant site to host large groups (up to 2,500 individuals is reported here) along coastline (Wildlife Division, 2010). Not many waders were encountered because many of them are migrants and were not expected to be numerous at Saadani in northern summer, and seashore was not intensively searched. Few woolly-necked storks were recorded along the beach. Previous literature (Marttila, 2011) indicates that this species is more frequent at Saadani than in any other park in Tanzania. This species breed in the coastal areas but seasonal movements is reported (Hancock *et al.*, 1992; Marttila, 2011), and there is a limited information on breeding season and sites. Additionally, the recording of Saddle-billed stork was of interest, it is not known to permanently reside in Saadani National Park.

CONCLUSION

The coastal, riverine, forest and plains that make up Saadani's landscape not only account for its diverse and abundant avifauna, but also provides hiding places for many of the secretive species. However, with 119 bird species, over 30% of the total birdlife in SANAPA, recorded in an area less than one third of the park revealed that the southern part of the park is an important site for birdlife. The park is indeed a birder's paradise. This study represents a hypothetic tourist visit plan for birding in the southern part of SANAPA during the dry season, a major touristic period for eastern Africa parks. The study gives information on the locally common bird species and those that require patient observers. Some of the species can be seen with the first hour of birding while others will require a night stay. This information is also crucial for park management as it could be used in the marketing strategy because it has been shown that the more the animal species the higher the motives for tourists to visit an area. Visitors of the southern part of Saadani National Park could combine birding and other services within the park such as boating along the Wami River and game viewing as many game species moves south to the Wami River the during dry season.

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DIET COMPOSITION OF THE GOLDEN JACKAL, CANIS AUREUS IN THE NGORONGORO CRATER, TANZANIA

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ABSTRACT

The Ngorongoro crater is known for having the highest density of carnivores in the world. In the past, most of the research focused on large carnivores such as lions and spotted hyenas. Medium sized carnivores such as jackals have received very little attention and the information on these carnivores is limited. Diet composition of golden jackal (Canis aureus) was studied in the Ngorongoro crater from July 2014 to May 2015 covering both dry and wet seasons using focal animal observation (direct method) and collection of faecal/scat samples from known individuals in the field (indirect method). In both seasons, insects (mostly dung beetles, family Scarabaeidae) formed the largest percentage of food items consumed (100% of scat samples analyzed). The frequency of occurrence of rodents was significantly higher in dry season (59.4%, n=19) than in wet season (28.9%, n=11), Mann-Whitney U test, p<0.0001, U=318.5). Additionally, 25% and 39.5% of scat samples contained plant materials of the family Cucurbitaceae in dry and wet seasons respectively. The jackals also fed on carrion of large herbivores (mainly wildebeest and buffalo). Seasonal variation in types of food was noted; in wet season, the jackals also consumed birds (Abdim's storks), medium sized mammals (Thomson's gazelle fawns) and in one incidence, three individuals were observed to hunt and feed on an adult Thomson's gazelle. The results suggest that the golden jackals are omnivorous and opportunistic in their feeding.

Key Words: Diet composition, dry season, golden jackal, Ngorongoro Crater, wet season.

INTRODUCTION

Ngorongoro Crater exhibits the highest density of predators in the world including lion (*Panthera leo)*, spotted hyena (*Crocuta crocuta*), jackal (*Canis* sp.), cheetah (*Acinonyx jubatus*), and leopard (*Panthera pardus*) (Swanson, 2007). For many years research in the area has been focused on large carnivores such as lion and spotted hyenas. Very little is known about medium-sized carnivores like jackals whose numbers are unknown (Swanson, 2007) and thus making this study important. The focus of the study was to investigate the diet composition of golden jackal in dry and wet seasons.

The three species of jackals; golden (common) jackal (*Canis aureus*), silver-backed (black-backed) jackal (*Canis mesomelas*) and the side-striped jackal (*Canis adustus*) coexist in the Ngorongoro crater, Tanzania. East Africa is the only region where all the three species of jackals coexist. Elsewhere each species exists alone or in sympatry with one other jackal species (Valkenburgh *et al*. 1994)

The golden jackal (*Canis aureus*) is the most widely distributed of the three jackal species. It is the only jackal species that occurs outside the Sub-Saharan Africa. The golden jackal occurs in North and East Africa, South-eastern Europe, Middle East and South Asia up to Burma and Thailand.

A recently published report by Koepfli *et al*. (2015) indicate that an African golden jackal and Eurasian golden jackals who have been long considered as one species are genetically distinct species and have independent lineages and that the African golden jackal most likely represents a separate species. The report further shows that the African golden jackal is phylogenically closer to gray wolves (*Canis lupus*) than to the silverbacked and sidestriped jackals. Morphologically, the African golden jackal and Eurasian golden jackal are very similar. However, until further confirmation is available, in this study the name "*Canis aureus*" is maintained to mean both African golden jackal and Eurasian jackal.

Due to tolerance of dry habitats and omnivorous diet, the golden jackal can inhabit a wide variety of habitats, from the Sahara Desert (except the most hyper-arid parts) and Sahel to the evergreen forests of Myanmar and Thailand. In Africa, the golden jackal typically prefers semi-desert, short to medium grasslands, and savannas (Moehlman & Jhala, 2013). Although the Golden Jackal is present in a number of protected areas across its wide range, including the Serengeti–Maasai Mara–Ngorongoro complex, there is evidence that some populations are declining due to anthropogenic causes (Jhala & Moehlman, 2004)

Information on dietary requirements is important in determining the animal's range for effective conservation and is of paramount importance to wildlife management authorities like Ngorongoro Conservation Area in planning for the management of the species and their habitats. Diet assessment is important in mammalian ecology as food availability influences population size, social organization and interspecific relationships and thus has important implications for conservation (Balestrieri *et al*., 2011).

Dietary studies on golden jackal in many parts of world indicate that the animal is an omnivorous and opportunistic forager (Lamprecht 1978; Moehlman 1983, 1986; Fuller *et al*., 1989; Vaughan, 1986; Moehlman and Hofer 1996 and Moehlman & Jhala 2013).

In the Serengeti National Park, although they consume invertebrates and fruit, over 60% of their diet is vertebrates and they will kill rodents, lizards, snakes, birds (from quail to flamingos), hares and gazelles. They also scavenge the carcasses of larger herbivores, such as Common Wildebeest *Connochaetes taurinus*, Plains Zebra *Equus quagga* and African Buffalo *Syncerus caffer* (Moehlman 1983, 1986, 1989; Moehlman and Jhala 2013).

Most studies on diet composition of jackals have been based on the analysis of faecal samples and a few studies have been based on stomach content analysis. Both are indirect methods, and the stomach analyses are not dependent on recording when the animal is defecating and the food items observed will be undigested materials. As frequency of occurrence relies on the presence of undigested hard parts in scats (faeces), any food which has a large proportion of soft material will be underestimated. So, in this study both direct observation and faecal analysis methods were employed to ensure more detailed data on diet composition of the golden jackal.

MATERIALS AND METHODS

Study site

Ngorongoro Crater is part of the Ngorongoro Conservation Area (NCA). The Ngorongoro Conservation Area (Fig. 1) was established in 1959 and is both a World Heritage Site and an International Biosphere Reserve. It is adjacent to Serengeti National Park and together they form the Serengeti–Maasai Mara–Ngorongoro ecosystem. It encompasses an area of 8,292 km^2 which includes the world famous Ngorongoro Crater. The Crater itself, including its walls, covers approximately 310km^2, and the floor of the Crater, where most wildlife resides, is 250km^2 (Swanson, 2007). Coordinates of the Ngorongoro crater are 3°5’ to 3°15’S and 35°25’ to 35°40’E (Swanson, 2007). There are two seasons; a dry season (from June to September) and a rainy season (from October through May). The yearly precipitation is < 600 mm in the north and > 900 mm in the south and southeast while daily mean of temperatures are between 24 ºC and 30 ºC in Ngorongoro Crater and sometimes range up to 38 ºC at Oltupai. Nights are cool or cold (close to 0 ºC) from June to August on the rim of the crater (Marttila, 2011). The dominant vegetation of the crater floor is tall and short grasslands (Swanson, 2007).

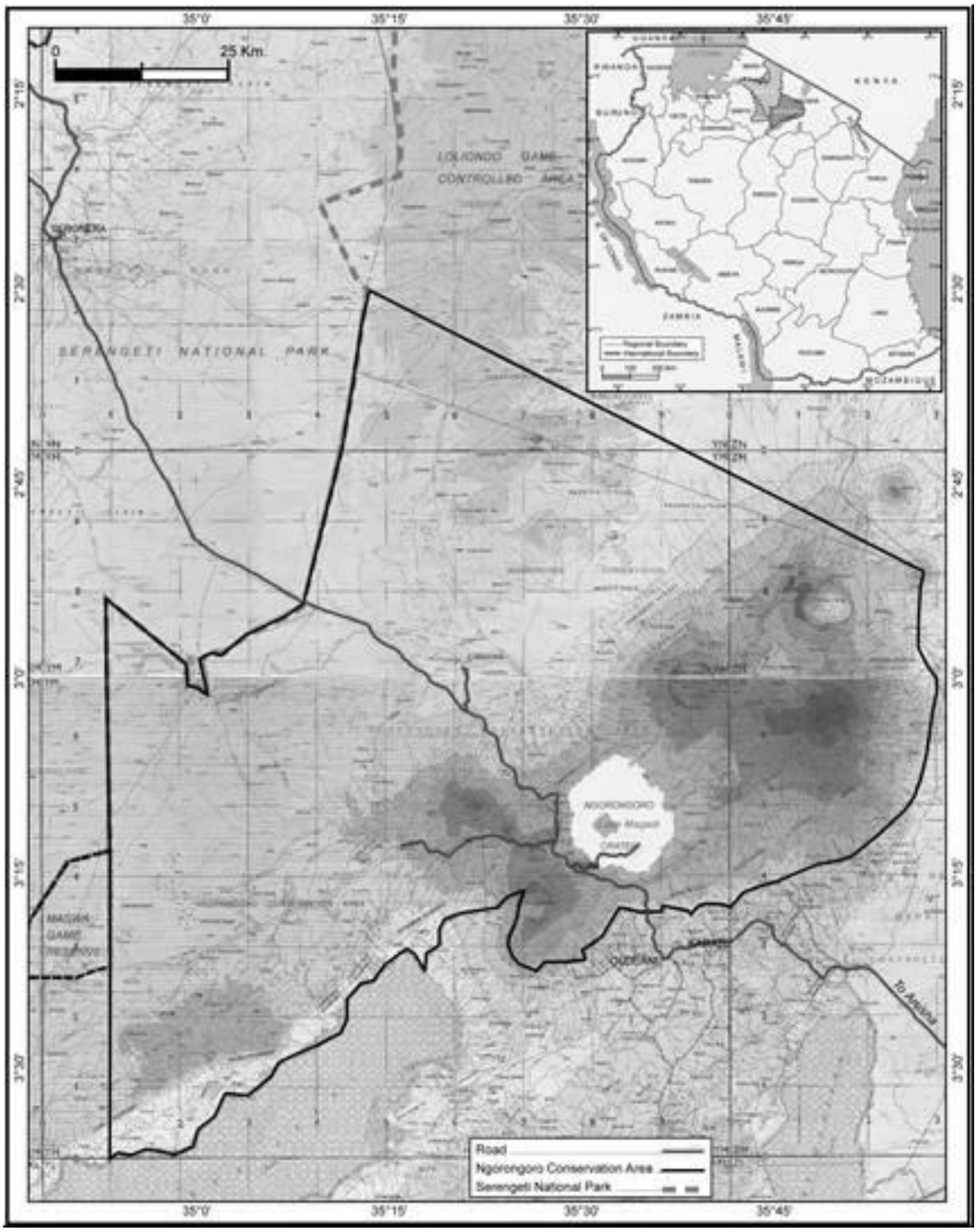

Figure 6: *Map of the Ngorongoro Conservation Area.*
Source: *Cartographic and Map Curating Unit, Geography Department, University of Dar es Salaam,* 2015.

Data collection

Direct observation

Individual golden jackals were followed in the field by four wheel drive vehicle from morning to evening and various aspects of feeding were recorded; these included food items observed being eaten, GPS location, time and habitat. The tracking program ensured that different individuals of different sexes were followed. Individuals were identified based on natural markings such as scars and ear notches. In addition, all activities were recorded including territorial marking and resting. The number of prey items hunted/consumed was recorded and the amount of food consumed was estimated. Data were collected in dry season (July-October, 2014) and wet season (Jan-May, 2015).

Indirect method (Scat collection and analysis)

The indirect method involved collection of faecal/scat samples from known individuals in the field and later analyzed (sorting and identification of undigested food items in the scats). The percentage occurrence of different food items (a measure of how common a food item is in jackal's diet) in individuals' scat samples were analysed and compared between dry and wet seasons.

RESULTS

Direct method

In dry season (July-December, 2014), food/prey items fed on by golden jackal were insects, rodents, scavenged items (carrion) and bat eared-fox (n=1). In the wet season (Jan-May, 2015) the food/prey items were insects, rodents, carrion, wildebeest placenta, birds (Abdim's stork), Thomson's gazelle's fawns and adult Thomson's gazelle (n=1). In both seasons; insects were the most frequent prey item followed by carrion and rodents (Fig. 2). Carrion of large herbivores (mainly buffaloes and wildebeest) was consumed in both seasons. The amount of carrion consumed was higher in dry season (mean: 591 ± 131g per carcass) than in the wet season (Mean 377±153g per carcass) although the difference was not significant (Mann-Whitney U test, $p>0.05$, $U=44.5$), Fig. 2 and 3. Availability of other food types such as gazelle fawns, wildebeest placenta and birds in wet season may partly account for less carrion consumed. Quantitatively, carrion contributed the highest amount to jackal's diet (Mean: 591 ± 131g per carcass and 377±153g per carcass in dry and wet seasons respectively) as compared to rodents (Mean: 115g and 100g in dry and wet season respectively) and insects (Table 1). Although the latter had the highest percentage frequency of occurrence (100% in each season), their contribution to jackal's diet was lowest (Mean: 30g and 55g) in dry and wet season respectively), Table 1. Insects belonging to family Scarabaeidae, order Coleoptera (dung beetles) were frequently eaten in both seasons (Table 2 and 3). Means of weight estimates of food items consumed in relation to days observed are presented in Table 1.

Indirect method

A total of 32 faecal/scat samples in the dry season (July -December, 2014) and 38 samples in the wet season (Jan-May, 2015) were collected and analysed. Insects (mainly dung beetles), small mammals (rodents), carrion (of large herbivores; buffaloes and wildebeests) and plant materials (fruits of Cucurbitaceae family) constituted the jackals' diet in both seasons. Bird remains were found in scats collected during the wet season in addition to the mentioned food items. Insects were frequently eaten (found in all scats analysed). The percentage occurrence of dung beetles (family Scarabaeidae, order Coleoptera) was significantly greater in the scats (65.6%, n=21) as compared to other insect families (Kruskal-Wallis test, $p<0.001$), in the dry season (Table 2). Likewise, in the wet season, insects (mostly dung beetles, family Scarabaeidae) formed the largest percentage of food items consumed (100% of scat samples analyzed, n=38). Family Scarabaeidae had the highest percentage frequency of occurrence among the insects consumed by the jackals (89.5%, n=34) as compared to other insect families all combined (21.1%, n=8) and the difference was significant, Mann- Whitney U test, $p<0.001$, U=228), Fig. 3 and Table 3.

Frequency of occurrence of rodents was significantly greater in the dry season (59.4%, n=19) as compared to the wet season (28.9%, n=11), Mann-Whitney U test, $p<0.0001$, U=318.5), Fig. 3.

There was no significant difference in amount of plant materials consumed between the two seasons (Mann-Whitney U test, $p<0.05$, U=580) although jackals appeared to feed more plant materials during the wet than dry season.

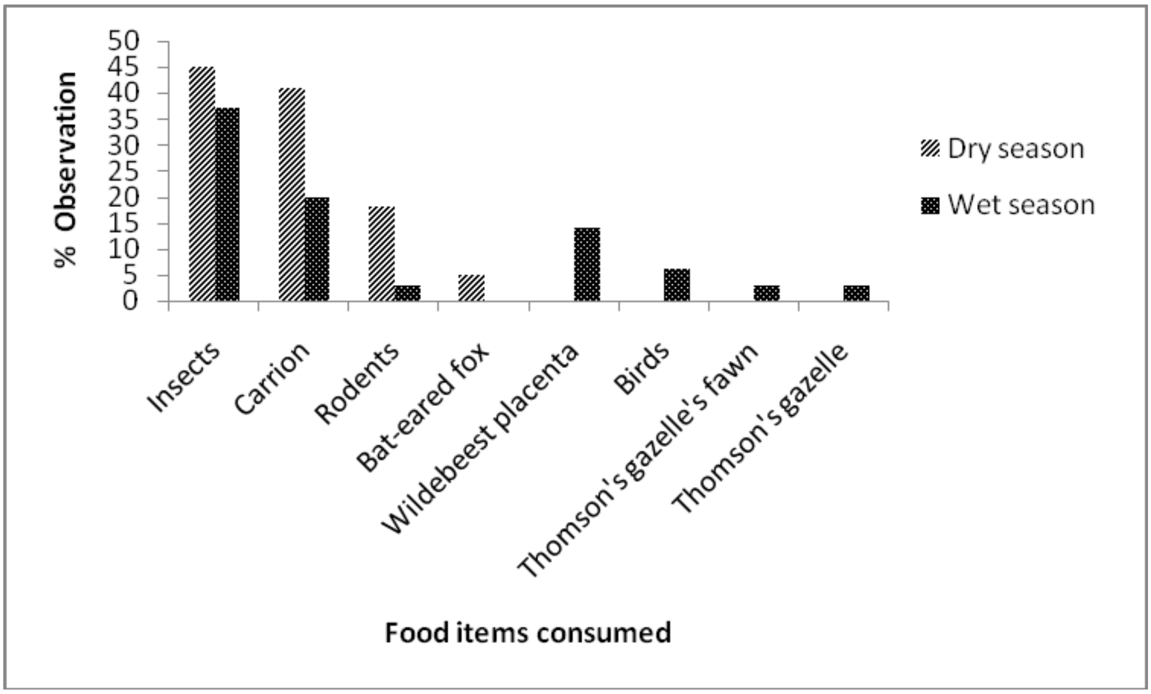

Figure 7: *Percentage of observed food items consumed by golden jackals in dry and wet seasons in Ngorongoro Crater. Percentage observed = (number of days observed feeding on particular food item/total number of days observed in a given season) X 100.*

Table 1: Mean weight estimates of food items consumed by golden jackals for the days observed in dry and wet seasons.

Food item	**Eaten, hunted or scavenged?**	**Dry season**		**Wet season**	
		% Observations	**Mean weight of food consumed (g)**	**% Observations**	**Mean weight of food consumed (g)**
Insects	Eaten	45%	30	37%	55
Carrion	Eaten, Scavenged	41%	573	20%	377
Rodents	Eaten, Hunted	18%	115	3%	100
Bat-eared fox	Eaten, Hunted	5%	4000	0%	0
Wildebeest placenta	Eaten			14%	310
Birds	Eaten, hunted			6%	1200

Thomson's gazelle's fawn	Eaten, hunted	3%	3000
Thomson's gazelle adult	Eaten, hunted	3%	3000

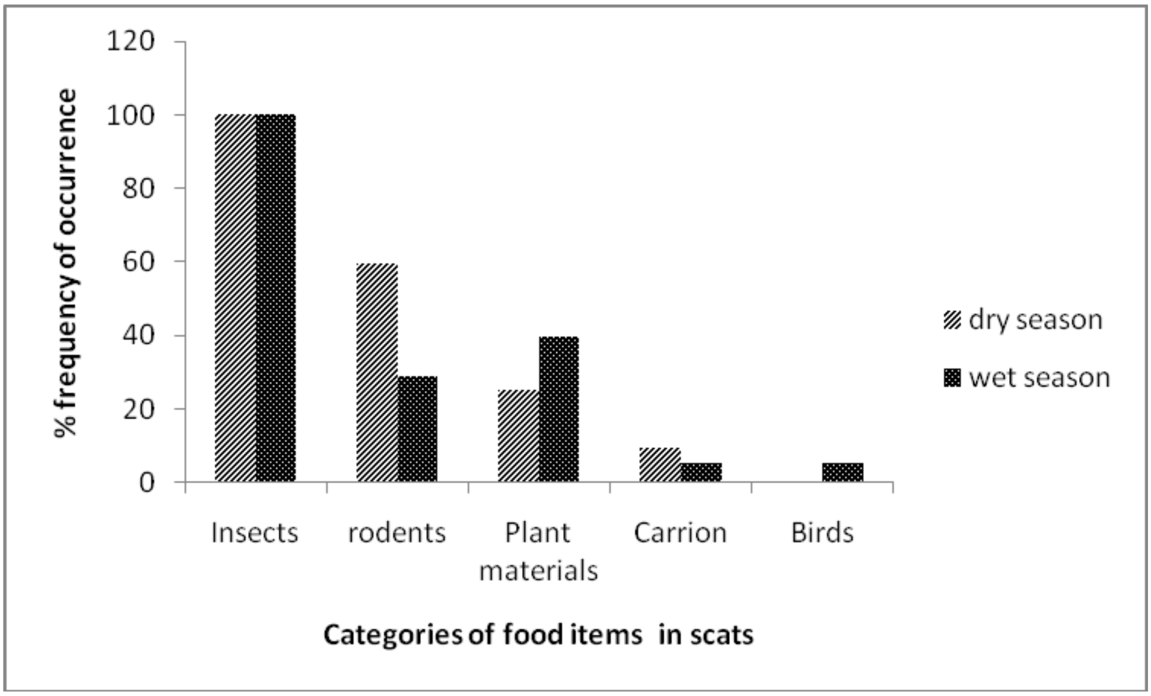

Figure 8: *Percentage frequency of occurrence of various food items found in scats of golden jackals in dry and wet seasons in Ngorongoro Crater. Percentage frequency of occurrence = (Number of scat samples containing particular food item/total number of samples collected in a given season) X 100.*

Table 2: Percentage frequency of occurrence of insects (families/orders) in the scats of golden jackals in the dry season.

Scarabaeidae (Order Coleoptera), dung beetles	**Calliphoridae (Order Diptera)**	**Formicidae (Hymenoptera)**	**Orthoptera**	**Unidentified invertebrates**
65.6%	25%	9.4%	15.6%	25%

Table 3: Percentage frequency of occurrence of insects (families/orders) in the scats of golden jackal in the wet season.

Scarabaeidae (dung beetles)	Others (Preying Mantis, Diptera, Trichoptera)
89.5%	21.1%

Plate 1: *A male golden jackal searching for dung beetles in elephant dung in the Ngorongoro crater during the wet season.*

Plate 2: *A male golden jackal feeding on Abdim's stork it hunted in the Ngorongoro crater during the wet season.*

Plate 3: *Three golden jackals feeding on the wildebeest carcass in the crater in the dry season. Golden jackals usually face competition from spotted hyenas, silver-backed jackals and vultures when feeding on carcasses.*

Plate 4: *Three golden jackals feeding on adult female Thomson's gazelle they hunted in the crater during the wet season.*

Plate 5: *A female golden jackal who had 3 pups, feeding on wildebeest placenta in the crater during the wet season.*

DISCUSSION

Results obtained in this study show that golden jackals have a varied diet consisting of both animal and plant foods. The diet also varies with seasons and depends on availability of food items. Opportunistic feeding is one of the reasons for the success of the golden jackals and other members in the family Canidae (Vaughan, 1986). Seasonality in terms of quantity and types of food items was reflected in the diet of golden jackals. Lesser amount of rodents consumed in the wet season as compared to the dry season may be due to availability of more food types during that season or that the dry season is the peak breeding season for the rodents. For example, Abdim's storks (a migratory bird, 1.2 kg live weight) were abundant at the beginning of the wet season, and they were scattered all over the short grasslands in the crater, the preferred habitat for golden jackals. These storks were hunted by the golden jackals. The hunting was usually performed by a single individual and the kill usually was taken to a den to be shared by the rest of the family group members including pups.

The wet season was the whelping (breeding) season for the golden jackals. The whelping season of this jackal species may reflect the availability and abundance of food (Moehlman, 1983). If the pair has pups they usually go back to their den and regurgitate the food to their pups. The wet season is also a breeding season for wildebeest and Thompson's gazelle (Swanson, 2007). Golden jackals were observed to follow the wildebeest and feed on their placenta as they gave birth to calves (results in Table 1). Golden jackals opportunistically hunted Thomson's gazelle fawns. Hunting was usually performed by a pair of golden jackals and the hunted fawn was usually equally shared between the male and female. Similar observations were reported by Moehlman (1983). Hunting in pairs increases the hunting success of jackals (Lamprecht 1978; Moehlman & Hofer 1996). The golden jackals also were observed to cooperatively hunt and feed on adult Thomson's gazelle (20kg) (n=1), Table 1, Plate 4. Depending on food availability, golden jackals may be solitary hunters or hunt as co-operating in pairs or groups (Mondal *et al.*, 2012). This behaviour was also observed during this study.

Several studies conducted on diets and feeding habits of golden jackals in different parts of the world have shown that golden jackals are omnivorous and opportunistic foragers (Lamprecht, 1978., Moehlman, 1983, Fuller *et al.*,1989., Radovic & Kovacic, 2010, Mondal *et al.*, 2012, Moehlman & Jhala, 2013). These studies agree with the findings of this study. Opportunistic foraging allows golden jackals to feed on available food items that are less costly energetically. Moreover, the study results agree with observations obtained by Lamprecht (1978) on diet of golden jackals in the Serengeti National Park which basically form one ecosystem with Ngorongoro crater. He found that golden jackals consumed carcasses of large herbivores, hunted gazelle fawns, rodents, birds and ate insects and vegetable matter.

Prey availability, size and vulnerability influence food choice by golden jackals. For example, insects belonging to family Scarabaeidae, order Coleoptera (dung beetles) were frequently eaten in both seasons as pointed out in the results (Table 2 and 3). The jackals were observed to regularly inspect/check dungs of large herbivores such as elephants, buffaloes and zebras for dung beetles during their foraging trips (Plate 1). The fact that dung beetles were eaten more often may be due to their availability and vulnerability (cannot easily escape) as compared to other flying insects like grasshoppers, which were opportunistically caught and consumed. The golden jackals were sometimes seen jumping to catch flying insects but in most cases the attempts were not successful. These results agree with other findings including Radovic & Kovacic (2010) where Coleoptera were one of the important orders of insects in the diet of golden jackals in Croatia. When a carcass especially of big herbivore such as a buffalo, wildebeest or zebra is located, jackals normally spent most of the time feeding on it and caching what they cannot consume. Golden jackals also feed on wildebeest placenta in the wet season (Plate 5) when they are plentiful and available. Golden jackals were observed to follow the wildebeest and feed on their placenta as they give birth to calves. Plant items were not observed being fed by jackals in the field but seeds of family Cucurbitaceae were found in their scats in both seasons indicating the importance of plant food materials to jackals and further confirming the omnivory feeding habits of jackals. A study by Mondal *et al*., (2012) in Sariska Tiger Reserve, Western India suggested that vegetable matters had maximum contribution to the golden jackal's diet followed by rodents. Furthermore, rodents were observed to represent a primary food for jackals in Bulgaria (Markov & Lanszki, 2012) as such underscoring the similarity of the findings of this study with those conducted elsewhere.

CONCLUSION

The study provides further confirmation that golden jackals are omnivorous and opportunistic foragers whose diet is reflected by the availability of food items in their habitats. Insects, rodents, carrion and plant materials are the main food items for the golden jackals in the dry season in Ngorongoro crater. Additionally, Abdim's storks, Thomson's gazelle's fawns and wildebeest placenta are also essential food source for the golden jackals in the wet season which is also a breeding season for the golden jackals.

RECOMENDATIONS

It is recommended that further study on diets of golden jackals be conducted in areas outside the crater where the jackals are also known to occur. Furthermore, in this study observations where made during the day time only and therefore it is recommended that a future study be conducted in both day and night in order to have a better information on the diet composition of golden jackals at night since the animals are known to be active at night too. Night data collection will also enable the study of *C. adustus*, another jackal species which is typically nocturnal (and rarely seen during the day) in the area and thus provide an opportunity to make comparisons of the diets of all the three species of jackals coexisting in the area, that is *C. aureus, C. mesomelas* and *C. adustus*.

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COMMUNAL KNOWLEDGE AND PERCEPTIONS OF AFRICAN WILD DOG *(Lycaon pictus)* REINTRODUCTION IN THE WESTERN PART OF SERENGETI NATIONAL PARK, TANZANIA

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ABSTRACT

This study assessed community knowledge and perceptions regarding the reintroduction of the African wild dog (Lycaon pictus). Questionnaires were employed to acquire information from 216 randomly selected respondents within six villages. Our results indicated that gender differences exist among respondents; more males than females correctly identified wild dogs from photo cards. Males also wanted the species to be of high conservation priority. Moreover, because of their education, more males suggested that the wild dog population should increase after being released into the Serengeti National Park (SNP). Finally, gender and education level significantly explained the variation of the outcome of answers with respect to wild dog reintroduction to SNP. The study recommends that conservation authorities should incorporate community knowledge and perceptions during implementation of the wild dogs' reintroduction programmes.

Key words: Gender, education, conservation priority, protected areas, reintroduction

INTRODUCTION

Worldwide, most communities living adjacent to protected areas are knowledgeable about wildlife behaviour (Gandiwa, 2012; Lagendijk and Gusset, 2008; Thorn *et al*., 2011; Lescureux and Linnell, 2010) and management (Uddin and Foisal, 2007; Ogada *et al*., 2003; Mills, 1991; Lagendijk and Gusset, 2008; Kideghesho et al., 2007; Kaltenborn et al., 2006; Inskip *et al*., 2016). Previous studies have shown that communal knowledge has been widely applied by scientists and policy makers as source of ideas for ecosystem management and ecological restoration (Folke, 2004; Gadgil *et al.*, 1993; Hayward et al., 2007; Gusset *et al.*, 2006; Gusset *et al.*, 2010; Sjölander-Lindqvist *et al.,* 2015). Therefore, indigenous knowledge has been used by researchers to evaluate wildlife interactions with their environment (Scholte, 2011; Gadgil *et al.*, 1993; Mwakatobe *et al.*, 2012; Kideghesho *et al.*, 2007; Holmern *et al.*, 2007; Lembo *et al.*, 2008).

Previous studies have shown that information focused on communal knowledge of protected area management and predators are well recognized by decision makers (Kaltenborn *et al.,* 2006; Tessema *et al.*, 2010; Kideghesho et al., 2007; Lindsey et al., 2005; Sjölander-Lindqvist et al., 2015; Smith *et al.*, 2014). Studies addressing such people's perceptions of large carnivore management are well documented in several ecosystems in Tanzania (Goldman *et al.,* 2010; Koziarski *et al.*, 2016; Dickman *et al.*, 2014). Therefore, it is essential from both a scientific and conservationist perspective to understand communal knowledge on wildlife conservation (Taylor, 2009; Kideghesho, 2008).

Studies have shown that both positive and negative human perceptions are affected by gender and education level (Røskaft et al., 2007; Conforti and de Azevedo, 2003; Andersone and Ozolinš, 2004; Røskaft *et al.*, 2003). Having that in mind, conservation authorities have taken into consideration different suggestions in undertaking species-appropriate conservation measures (Andersone and Ozolinš, 2004; Okello *et al.*, 2011; Abram *et al.*, 2015; Koziarski et al., 2016). Several studies have reported that negative perceptions of carnivores in the local community land are due to conflict with farmers or human attack (Gusset *et al.*, 2008; Lescureux and Linnell, 2010; Inskip *et al.*, 2016). Thus, scientists have been incorporating human perceptions into approaches for managing biodiversity (Gandiwa, 2012; Gusset et al., 2010; Okello *et al.*, 2011; Caruso and Pérez, 2013; Gadgil *et al.*, 1993).

The study by Okello et al. (2011) suggested that sustainable animal species conservation and management requires routine knowledge of species interaction with the community and ecosystem functions. Most educated people living around protected areas have played a central role in managing carnivore species due to their better understanding on the importance of natural resources conservation in protected as well as open areas in community land (Gusset et al., 2006; Lagendijk and Gusset, 2008; Lindsey *et al.*, 2005). Management of large carnivores is a difficult task, which requires good governance and thorough understanding of human interactions with wildlife species and habitats (Sjölander-Lindqvist et al., 2015; Jacobsen and Linnell, 2016; Megaze *et al*., 2017; Redpath *et al.*, 2013). Studies have shown that the African wild dog (*Lycaon pictus*) can be successfully managed as a metapopulation through the involvement of ranch owners and bordering communities (Gusset et al., 2008; Lindsey et al., 2005). Despite these findings, studies on communal knowledge and perceptions of wild dog conservation in the western Serengeti ecosystem are scant. Wild dog packs have not been sighted inside the Serengeti National Park (SNP) since its local extinctions in the early 1990s (Ginsberg et al., 1995; Holmern *et al*., 2007). Since Tanzania holds large populations of large carnivores (Riggio et al., 2013; Dickman et al., 2014), the African wild dogs have received high protection status due to its recent decline (TAWIRI, 2009). Reintroduction of African wild dogs is necessary in the SNP due to its high tourism potential. Also, such reintroduction will reduce human-wild dog conflicts in Loliondo Game Controlled Area and improve the protection of this species in the area. Because of its wide-ranging behaviour, conserving wild dogs requires integrating community knowledge and perceptions due to the ability of wild dogs to live in human-dominated landscape. Therefore, this study hypothesized that communal knowledge and perceptions of African wild dog reintroduction and conservation would be influenced by gender and education levels in the study area.

MATERIAL AND METHODS

Study area

The study was conducted in western Serengeti focusing on eastern part of the Simiyu region which covers an area of 23,808 km^2 bordering Maswa Game Reserve (MGR) and SNP, between latitudes 2° and 4° S and between 33° and 35° E (Figure 1) (URT, 2013). The area is characterized by high human population; totaling 2 million people with an annual growth rate of 2.8%, due to increased birth rates and immigration, of which Sukuma tribe is dominant (Nuno et al., 2014; NBS, 2012; Sinclair et al., 2008). Communities' main economic activities include agriculture with main crops being maize, sorghum, cotton and cassava, and livestock keeping (NBS, 2012; Meertens et al., 1995). There are fewer wildlife species remaining adjacent to MGR due to habitat destruction (Songorwa, 2004), while the area inside the SNP has a high diversity of wildlife including herbivores, carnivores and birds (Sinclair et al., 2002; Sinclair et al., 2008). The topography of the area is characterized by flat, gently undulating hills and low hills, sparse vegetation, with some places covered with miombo woodland (URT, 2013). Rainfall usually starts in October and ends in May, and the rainfall ranges from 600 mm to 900 mm (URT, 2013) and is influenced by Lake Victoria through tidal rythms generated by temperature differences between the lake and the land (Campbell and Hofer, 1995; Norton-Griffiths et al., 1975). The temperature ranges from 18° C to 31° C annually (URT, 2013). The soils are dominated by heavy black soils with areas of red loamy and sandy soil (Meertens et al., 1995).

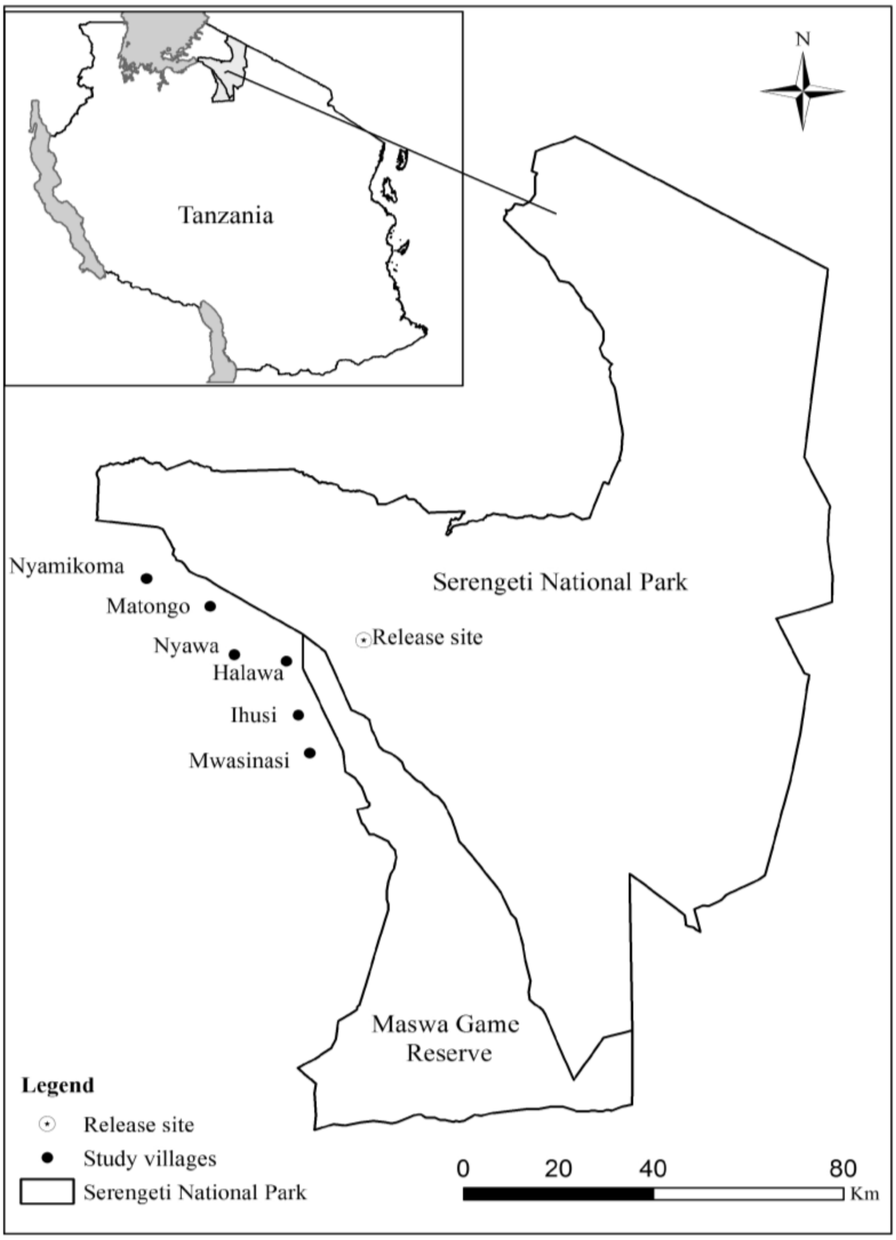

Figure 1. *Map of Tanzania showing the study area and surveyed villages in the Western part of the Serengeti National Park.*

METHODS

Data were collected in August 2012 from six villages, namely Nyamikoma, Matongo, Nyawa, Halawa, Ihusi and Mwasinasi and were purposively sampled (Figure 1) at gradient distance of 0 to 10 km from the park boundary. Prior to the interview, researchers explained the main purpose of the study to the village authorities. Permission for conducting interviews was then granted. For this study, the household was regarded as a sampling unit. Respondents above 18 years old were assigned numbers obtained from the village register book. Each number was written on a piece of paper, folded and placed inside a box from which 36 respondents were randomly picked for interview. Randomized face-to-face semi-structured interviews, using both open and closed questions, were then conducted with 216 respondents. The researchers interviewed each respondent by asking open-ended questions that allowed respondent to answer freely. In addition, close ended questions with limited answers (i.e. yes or no) were also used. The researchers developed clear judgments on respondents' (his/her) understanding regarding the asked question. The language used to interview people was *Swahili*, and where necessary it was translated to the *Sukuma* language with the help of a local field assistant with a secondary education background. Before the interview, each question was explained to the respondent in order to obtain meaningful answers. Socio-demographic variables including gender, age, job status and education level were used to assess respondents' knowledge and perceptions in respect to above questions.

Data analysis

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS version 21, Chicago, USA) to analyze the data. We used descriptive statistics to summarize the questionnaire response data. Since most of our data were categorical, we performed Pearson's chi-square analyses to determine the differences in the independent variables that explain communal knowledge and perceptions. Furthermore, we used linear regression analyses to determine the factor that contributed most to statistical significance. All statistical tests were two-tailed and significant level was set at $P < 0.05$.

RESULTS

Respondent general information

Of all interviewed respondents (n = 216), 69 % were men, 80% of the total interviewed people were between 18 and 45 years, 14 % were between 46 and 60 years, and 6 % were older than 60 years of age. Majority of them 60 % (n= 2016) had primary education, 24 % had never been to school and fewer 16 %, had secondary education and above. The majority of the respondents were farmers (87 %) while the remaining 13 % were businessmen, government employees and students.

Knowledge about African wild dogs

The majority of men correctly identified African wild dogs from the photo card, compared to women (χ^2 = 31.27, df = 1, P < 0.001; Table 1). Conversely, age (P = 0.360), education level (P = 0.547) and job status (P = 0.241) had no effect on respondents' ability to recognize African wild dogs. Furthermore, statistically significantly more men than women suggested that African wild dogs should be given high conservation priority status (χ^2 = 13.59, df = 3, P = 0.004; Table 2).

Table 1: Numbers and percentages of respondents who were able to identify African wild dogs from a photo in the Western part of the Serengeti National Park in relation to gender

Identified animal shown on the photo	Gender		Total N (%)
	Men N (%)	Women N (%)	
Yes	105 (70.5%)	20 (29.9%)	125 (57.9%)
No	44 (29.5%)	47 (70.1%)	91 (42.1%)
Total	**149 (100%)**	**67 (100%)**	**216 (100%)**

Table 2. Numbers and percentages of respondents regarding the level of conservation priority status that should be given to wild dogs in relation to gender

Conservation priority	Gender		Total N (%)
	Men N (%)	Women N (%)	
High	81 (54.4%)	23 (34.3%)	104 (48.1%)
Medium	11 (7.4%)	7 (10.4%)	18 (8.3%)
Don't know	26 (17.4%)	26 (38.8%)	52 (24.1%)
Low	31 (20.8%)	11 (16.4%)	42 (19.4%)
Total	**149 (100%)**	**67 (100%)**	**216 (100%)**

Respondents' perceptions of African wild dogs reintroduction into the SNP

Respondents had different opinions regarding what will happen to the wild dogs after the reintroduction into SNP. Generally, 72.5 % of the men believed that the wild dog population would increase after being reintroduced into SNP, while statistically significantly fewer women did (χ^2 = 7.18, df = 2, P = 0.020; Table 3). Furthermore, women had significantly more opinions than men about the outcome of reintroducing wild dogs into the SNP (χ^2 = 26.04, df = 3, P < 0.001, Table 4). Additionally, respondents with no education had significantly fewer opinions on the potential outcome of the reintroduction to SNP than educated people (χ^2 = 22.61, df = 6, P = 0.001, Table 5). Conversely, respondents with primary education suggested that tourism would increase (χ^2 = 22.61, df = 6, P = 0.001, Table 5). Using a linear regression model with method enter to the questions, "what are your opinions about reintroducing wild dogs back to SNP" as dependent variable and gender and education level as independent variables was statistically significant (F = 11.096, df = 2 and 213, P < 0.001, r^2 = 0.092). Both gender (t = 3.981, P < 0.001) as well as education level (t = -2.145, P = 0.033) were statistically significant demographic independent variables in explaining this variation.

Table 3. Numbers and percentages of what respondents believed would happen to the African wild dog population after release into SNP in relation to gender

After African wild dog release the species will	Gender		Total N (%)
	Men N (%)	Women N (%)	
Increase	108 (72.5%)	38 (56.7%)	146 (67.6%)
No opinion	25 (16.8%)	22 (32.8%)	47 (21.8%)
Decrease	16 (10.7%)	7 (10.4%)	23 (10.6%)
Total	**149 (100%)**	**67 (100%)**	**216 (100%)**

Table 4. Numbers and percentages of respondents' opinions on the outcome of African wild dog reintroduction to SNP in relation to gender

Opinion about release of wild dogs into SNP	Gender		Total N (%)
	Men N (%)	Women N (%)	
It will be a tourist attraction	48 (32.2%)	14 (20.9%)	62 (28.7%)
A Stronger protection of the species	44 (29.5%)	4 (6.0%)	48 (22.2%)
It is a dangerous animal that should be removed from human-dominated areas	16 (10.7%)	10 (14.9%)	26 (12.0%)
I don't know	41 (27.5%)	39 (58.2%)	80 (37.0%)
Total	**149 (100%)**	**67 (100%)**	**216 (100%)**

Table 5. Numbers and percentages of the respondents' opinions on the outcome of African wild dog reintroduction to SNP in relation to education level

Opinion about release of wild dogs into SNP	Level of education			Total
	No education	Primary education	Secondary and above	
Tourist attraction	9 (17.0%)	43 (33.3%)	10 (29.4%)	62 (28.7%)
Stronger protection of the species	6 (11.3%)	32 (24.8%)	10 (29.4%)	48 (22.2%)
It is a dangerous animal that should be removed from human-dominated areas	7 (13.2%)	19 (14.7%)	0 (0.0%)	26 (12.0%)
I don't know	31 (58.5%)	35 (27.1%)	14 (41.2%)	80 (37.0%)
Total	**53 (100%)**	**129 (100%)**	**34 (100%)**	**216 (100%)**

DISCUSSION

Respondents' knowledge of African wild dogs

Our findings suggest that men are more knowledgeable than women in identifying African wild dogs and also proposed a higher conservation priority status for the species. This is probably because in agro-pastoral communities, more men attend formal education than women (URT, 2010), and the former are also more powerful in the society, while the latter are not allowed to provide information in the presence of men (Assenga et al., 2016). Furthermore, we noted that in the Sukuma tribe men are engaged in social activities, such as listening to the radio, dancing and watching television programs that may increase the exchange of ideas from one person to another. Our results are consistent with earlier studies that have suggested that gender differences exist in levels of conservation knowledge (Dickman et al., 2014; Lyamuya et al., 2016; Kaltenborn et al., 2006; Nombo et al., 2015; Clamsen and Røskaft, 2013; Allendorf and Allendorf, 2012). Males may have suggested high conservation priority status for the species because of awareness of reporting on local extinction of African wild dog in early 1990s within the Serengeti ecosystem (Ginsberg et al., 1995; Burrows et al., 1994). Therefore, our findings support our hypothesis that gender is an important demographic factor explaining communal knowledge about African wild dog conservation.

Respondents' perceptions of African wild dogs reintroduction into the SNP

Results suggested that males believe that the African wild dog population would increase after reintroduction into the western part of the Serengeti ecosystem where presently the species is rarely seen. This is probably because of high diversity of prey species in the park, which is influenced by resource distribution (McNaughton and Georgiadis, 1986; Fryxell et al., 2005; Sinclair, 2003; Sinclair et al., 2008) that would lower the incidence of wild dogs moving outside the park. These authors pointed out that lack of human-wild dog conflict in the area was because wild dogs have not been sighted for several decades (Holmern et al., 2007). The community in western Serengeti would wish to see the African wild dogs in their area probably due to lack of experience of human-wild dog conflict. These findings are also in support of the previous studies (Lindsey et al., 2005; Nilsen et al., 2007; Smith et al., 2014).

The majority of our respondents, independent of gender and education level, acknowledged that they did not know the outcome of the released wild dog packs into SNP. Our study findings, suggest that respondents are not fully involved in the management of natural resources. Contrary to this observation, studies elsewhere have reported that local residents living close to protected areas are aware of ongoing conservation activities conducted by authorities in the protected areas (Yen et al., 2015; Mcgovern and Kretser, 2015; Piédallu et al., 2016; Caruso and Pérez, 2013; Inskip et al., 2016; Gandiwa, 2012; Megaze et al., 2017). Concurrently, our data also suggest that educated respondents acknowledged that the presence of more wild dog packs in the SNP following release will lead to an increased tourist attraction. Furthermore, other studies have suggested that education level plays an important role on people's perceptions about wildlife conservation (Lagendijk and Gusset, 2008; Conforti and de Azevedo, 2003; Megaze et al., 2017; Redpath et al., 2013). Given this fact, it is important to sensitize and conduct more research on large carnivores in this part of the Serengeti ecosystem. Hence, the community expressed positive opinions about the conservation of African wild dogs in their area as they anticipate wild dogs are important as a source of economic incentives in the future. The respondent's opinions will form the baseline information for management authorities of the wild dogs in the area after reintroduction. These findings supports our hypothesis that communal perceptions of African wild dogs' conservation, are mostly influenced by gender and education levels.

CONCLUSIONS AND RECOMMENDATIONS

This study concludes that both gender and education level are significant in explaining variations between community knowledge of and perceptions towards wild dog reintroduction and conservation in the western Serengeti ecosystem because they supported the release of wild dogs in the area. Moreover, because of their knowledge males believed the African wild dog should be a high conservation priority in their area. The study recommends that conservation authorities should incorporate communal knowledge and perceptions of local people during implementation of the wild dogs' reintroduction programmes. Future studies should be directed towards this part of the ecosystem to explore the large carnivores' presence and local peoples' attitudes towards the future existence. Additionally, we recommend that after the reintroduction exercise ended the same community should be interviewed to evaluate the increase of awareness and knowledge of African wild dogs.

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DOES SEASONAL VARIATION AFFECT TROPICAL FOREST MAMMALS' OCCUPANCY AND DETECTABILITY BY CAMERA TRAPS? CASE STUDY FROM THE UDZUNGWA MOUNTAINS, TANZANIA

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ABSTRACT

The increasing use of camera trapping coupled to occupancy analysis to study terrestrial mammals has opened the way to inferential studies that besides estimating the probability of presence explicitly consider detectability. This in turn allows considering factors that can potentially confound the estimation of occupancy and detection probability, including seasonal variations. To address this, we conducted a systematic camera trapping survey in the Udzungwa Mountains of Tanzania by deploying 20 camera traps for 30 days in dry and wet seasons, and used dynamic occupancy modelling to determine the effect of season on estimated occupancy and detectability for species with > 10 capture events. The sampling yielded 7,657 and 6,015 images in dry and wet seasons, respectively, belonging to 21 mammal species. Models with no season-dependency and with season-dependent detectability were best supported, indicating that neither colonization nor extinction varied with seasons, and that occupancy too did not vary. Only bush pig (Potamochoerus larvatus) showed a significant decrease in detectability from dry to wet seasons. Our study indicates that seasonal variation may have limited effect on occupancy and detectability of resident mammals in tropical forests, however it remains a factor to consider when designing camera trapping studies.

Keywords: Detection probability, occupancy, tropical forest mammals, Udzungwas

INTRODUCTION

Tropical rainforests generally experience relatively little seasonal changes in temperature and photoperiod compared to temperate habitats (Primack & Corlett, 2005; Williams & Middleton, 2008; Ghazoul & Sheil, 2010), however seasonal fluctuations in rainfall are pronounced and most tropical forests experience alternating wetter and drier seasons to a varying degree (Kato *et al.,* 2000; Primack & Corlett, 2005). This, in turn, have important implications on the resource availability, and hence on the activity patterns and movements, of forest-dwelling animals, including mammals (Babaasa 2000; Shannon *et al.,* 2010; Djagoun *et al.,* 2013; Gaidet & Lecomte, 2013; White, 2013; Gould & Gabriel, 2014). In spite of these implications, the effect of seasonal variations remains surprisingly little considered in ecological assessments of mammals. However, the recent, increasing application of camera trapping to the study of mammals using statistically-robust, inferential frameworks (MacKenzie *et al.,* 2002; 2006), has opened the way to studies that explicitly consider animal's detectability in the estimation of the state variable of interest, such as abundance or relative abundance. Specifically, occupancy is defined as the proportion of sites where a species is expected to occur, with detection probability being the probability that a species is not detected even if it is in fact present (MacKenzie *et al.,* 2002). Hence, such approach allows determining how factors such as seasonal variations affect detectability and occupancy. As detectability relates to the observation process, with the use of camera trapping it is known to vary with camera sensitivity due to climate parameters, including temperature and wetness (Rowcliffe *et al.,* 2011), providing a rationale for potential variation with seasons. In addition, animal behaviour related to shyness, elusiveness, or the varying use of trails where camera traps are set, as well as vegetation denseness, may also affect detectability (Rovero *et al.,* 2013; 2014a). More intuitive is the potential effect on occupancy, which may act both through the effect on detectability (upon which occupancy estimation is conditional) and as a direct effect of the above-mentioned variations in movements, resource use, and activity patterns.

We aimed to provide a contribution to this topic by conducting a systematic camera trapping study replicated in wet and dry seasons in the Udzungwa Mountains of the south-central Tanzania. This area contains the largest forested blocks in the Eastern Arc Mountains of Kenya and Tanzania (Rovero *et al.,* 2014b) and is particularly important for mammal diversity and endemism (Rovero & DeLuca, 2007). Camera trapping has been used extensively in the area (e.g. Rovero, Jones, & Sanderson, 2005; Rovero & De Luca, 2007; Bowkett *et al.,* 2008; Rovero *et al.,* 2013; 2014a), however this is the first study to address seasonality effects on mammals. We used a dynamic occupancy framework (MacKenzie *et al.,* 2003; MacKenzie *et al.,* 2006), which allows occupancy estimation over multiple 'seasons' with the explicit incorporation of detection probability. Our specific objective was to determine whether season had any effect on estimated occupancy and detection probability of forest dwelling mammals in the Udzungwa Mountains.

MATERIAL AND METHODS

Study area and seasonal variability

The Udzungwa Mountains of south-central Tanzania are a mosaic of moist forest blocks interspersed with drier habitats (Rovero *et al.,* 2013). This study was carried out in Mwanihana forest, on the eastern side of Udzungwa Mountains National Park (UMNP, 7°46'S, 36°51'E; Fig.1). Mwanihana is one of the largest forest blocks in the range (192 km^2 of closed forest habitat) with continuous vegetation cover from 300 to over 2000 m above sea level. The habitat types in the area contain deciduous forest on the low altitude to montane evergreen forest in the high altitude and ranges from east to west (Lovett *et al.,* 2006). Temperatures naturally follow an altitudinal gradient at all the times while seasonally, temperature rise to their peak in December/January (average 25°C), and fall to the lowest mean temperatures in June/July (average 11°C) each year (Jones, 2013). The total annual rainfall in Mwanihana forest is around 1500 mm from the two rainy seasons, with light and heavy rainy seasons start from November to February and March to May, respectively while the dry season spans from June to November (Rovero *et al.,* 2014a). Climate data records in the area for the past 50 years showed that dry seasons receive less than 30 mm of rainfall per month and wet seasons receive above 150 mm of rainfall per month (Global Climate Data, 2013). Such historical data concur with rainfall data recorded recently by the Tropical Ecology Assessment and Monitoring (TEAM) automatic weather station located within Mwanihana forest at 1200 m a.s.l. whereby during the dry season, i.e. July to October 2013 mean monthly rainfall was recorded at 10, 5, 12 and 8 mm of rains, respectively, while during the wettest months in 2014 (i.e. March to May) it was 150, 165 and 180 mm, respectively (TEAM Network, unpublished data). In addition, the area is home to about 45 endemic or near endemic vertebrate species to the Eastern Arc Mountains such as Sanje mangabey (*Cercocebus sanjei*) and Udzungwa red colubus *(Procolobus gordonorum)* (Rovero *et al.,* 2014b).

Data collection

We conducted systematic camera trapping surveys in the dry and wet season, by deploying 20 camera traps for 30 days at the same sampling locations. In the dry season, the data was collected from 3rd July to 13th August 2013 while in the wet season the survey was conducted from 1st April to 8th May 2014. Camera traps were placed on a regular grid in the southern part of the forest along most of the elevation gradient (300-2500 m a.s.l.), at a density of one camera per 2 km^2 following the standardized TEAM Network protocol (TEAM-Network, 2011; Rovero *et al.,* 2014a). Automated digital cameras with infrared flash (Reconyx RM 45 and HC 500 models, Reconyx Inc., Holmen, Wisconsin, USA) were used. Cameras were set to take photos without delay between consecutive triggers and tied to a tree about 2-3 m away from the wildlife trail located within a 100 m of radius in a proposed camera trap position at an average height of 50 cm. The cameras were angled to be parallel to the slope of the ground to maximize capture rate. Since cameras can operate on such period in autonomy, they were not checked to avoid unnecessary disturbance. At sampling completion, memory cards were recovered and mammal images extracted for identification using specialized software DeskTEAM (Fegraus *et al.,* 2011). A single taxonomic authority was used for species identification by following IUCN (2014). The data package for dry season was downloaded from the TEAM Network open-access repository (http://www.teamnetwork.org; ID: TV-20140227231705_4591).

Data analysis

We first assessed differences between seasons based on two descriptors from raw data in each season: (1) the observed species richness and (2) the camera trapping rates of species detected in both seasons. To compute camera trapping rate we scored events as the number of images filtered by 1 hour, that compromises between scoring the same individual multiple times and missing individuals (e.g. Mugerwa *et al.,* 2012; Rovero *et al.,* 2013; 2014a). We measured sampling effort as the number of 24-h periods from setting a camera trap in the field up until the camera was retrieved. We then calculated RAI as the ratio of events on camera days and multiplied by 100. We used Wilcoxon signed rank tests for paired samples to compare camera trap rates between seasons.

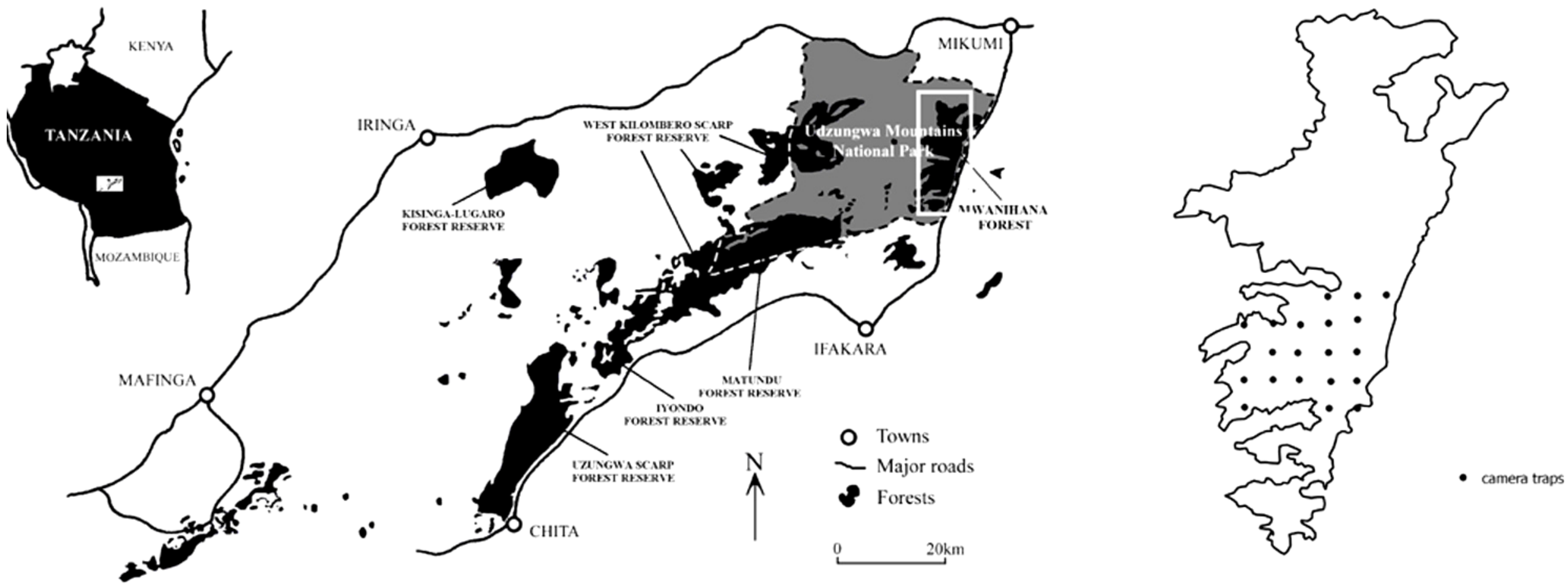

***Figure 1**:. Map of the Udzungwa Mountains of south-central Tanzania (adapted from Rovero et al., 2014b) showing the main blocks with closed-canopy forest. The study forest was Mwanihana in the northeastern portion of the range, which is zoomed to the right inset where the 20 camera trap sites on the south-central part of the forest are shown as black dots.*

We then used dynamic occupancy modelling (MacKenzie *et al.*, 2003) applied to species with enough trapping events for the analysis (i.e. >10 events). We followed a procedure described by Ahumada *et al.,* (2011) and Rovero *et al.,* (2013; 2014a) conducted in R software (R Development Core Team 2011). We defined occupancy (ψ) as the proportion of sites where a species is expected to occur, with detection probability (p) being the probability that a species is not detected even if present; these two parameters are estimated using a likelihood-based method (MacKenzie *et al.,* 2002). For each species, we built a matrix of detections (1) and non-detections (0) that aligned data for wet and dry seasons, made of camera trap sites by sampling occasions (8 for each of the two seasons), each sampling occasion being 5 days (Rovero *et al.,* 2014a). Unlike single-season models, the dynamic occupancy model allows to estimate the parameters governing changes in occupancy state variable in addition to p, namely colonization (γ) and extinction (ε) probability. We assumed that between seasons target populations would not experience colonization or extinction and therefore that occupancy levels would not change significantly, while we did assume that detectability could change. This could be a result of different climate affecting the detection process by the camera traps (Rowcliffe *et al.,* 2011) or different activity patterns due to varying habitat and resources conditions. However, because the different seasons being compared were in different years, with a time span of about 8 months in between (dry 2013 to wet 2014), we also considered models with time-dependent γ and ε. Thus, we evaluated four basic dynamic models as follows: (1) null model, with no time dependence (M0): $\psi(.)\gamma(.)\varepsilon(.)p(.)$, where (.) indicates that no effect of covariates is tested; (2) model with season-dependent detectability (M1):$\psi(.)\gamma(.)\varepsilon(.)p(\text{season})$; (3) model with season-dependent colonization and extinction $\psi(.)\gamma(\text{season})\varepsilon(\text{season})p(.)$; and (4) fully season-dependent model (M3): $\psi(.)\gamma(\text{season})\varepsilon(\text{season})p(\text{season})$. We implemented the modelling using package 'unmarked' in R (Fiske & Chandler, 2011; Fiske, 2015).We used the Akaike Information Criterion (AIC) to rank candidate models and calculate their Akaike weights, and considered AIC < 2 as the criterion to determine the best supported model/s (Burnham & Anderson, 2012). We derived ψ and p for both seasons by means of bootstrapping (Kéry & Chandler, 2012).

RESULTS

All 20 camera traps in the dry season worked successfully, while only 15 cameras worked in the wet season, due to either camera failure or production of blurred images preventing identification. Hence, we limited the analysis to data from the 15 camera sites that were sampled in both seasons, for a sampling effort of 466 (mean 31) and 449 (mean 30) camera days in dry and wet season, respectively. Sampling yielded a total of 7,657 and 6,015 images in dry and wet seasons, respectively. A total of 21 species of mammals from both seasons were photographed by the camera traps, of which 15 in both seasons, and three in each season only (Table 1). The number of species captured per camera was 2-9 (median 6) and 4-9 (median 6.5) in dry and wet season, respectively. Suni (*Nesotragus moschatus)* and bushy-tailed mongoose (*Bdeogale crassicauda)* recorded a difference of > 40 events between the two seasons whereas species like red duiker (*Cephalophus harveyi*) and Sanje Mangabey recorded a difference >30≤40 between the wet and dry seasons. Tree hyrax *(Dendrohyrax validus)* recorded 29 events during the dry season as opposed to two events during the wet season while bush pig (*Potamochoerus larvatus)* recorded 15 events in the wet season as opposed to 34 events during the dry season. The remaining species had a difference of < 10 events but three species namely Lowe's genet *(Genetta servalina lowei),* Sykes' monkey (*Cercopithecus mitis)* and yellow baboon (*Papio cynocephalus)* had similar events between the two seasons (Table 1). The Wilcoxon paired-sample test results on the photographic events for the 15 mammal species captured in both seasons was significant ($P<0.05$) only for the bushy tailed mongoose and marginally significant ($P<0.1$) for tree hyrax and suni (Table 1).

Six species of mammals that had enough events (>10), in each season for dynamic occupancy modelling, and model selection showed that for all species the best candidate models based on minimizing AIC were both Mo and M1, i.e. indicating that models with no season-dependency and with season-dependent detectability were both best supported (Table 2). Hence, colonization and extinction did not vary with seasons, and hence occupancy too did not significantly vary (Fig. 2). The only exception was bush pig, for which M3 and M1 were best models with almost identical AIC, indicating a significant variation (decrease) of detectability (Table 2, Fig. 2).

Table 1. Checklist of mammals camera-trapped in Mwanihana forest, Udzungwa Mountains, Tanzania in dry and wet seasons with threemeasures of occurrence: independent photographic events, camera-trapping rate as a relative abundance index (RAI) and naïve occupancy. Outcomes of Wilcoxon paired-sample test for differences in events between seasons are also indicated

		Events by hours		RAI		Naïve occupancy		Wilcoxon test	
Scientific name	**Common name**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Z value**	**P value**
Atilax paludinosus	Marsh mongoose	3	5	0.64	1.11	0.13	0.13	3.5	0.713
Bdeogale crassicauda	Bushy tailed mongoose	164	77	35.19	17.15	0.93	0.8	49	< 0.05
Cephalophus harveyi	Harvey's duiker	184	215	39.48	47.88	0.8	0.93	50.5	0.608
Cephalophus spadix	Abbott's duiker	6	8	1.29	1.78	0.27	0.4	5	0.583
Cercocebus sanjei	Sanje mangabey	26	66	5.58	14.7	0.6	0.73	25	0.154
Cercopithecus mitis	Sykes' monkey	3	3	0.64	0.67	0.13	0.13		
Cricetomys gambianus	Giant pouched rat	119	142	25.54	31.63	0.8	0.73	27.5	0.386
Dendrohyrax validus	Tree hyrax	29	2	6.22	0.45	0.33	0.13	19.5	0.073
Genetta servalina	Lowe's servaline genet	6	6	1.29	1.34	0.27	0.2	12	0.842
Hystrix africaeaustralis	Crested porcupine	NA	1	NA	0.22	NA	0.07		
Loxodonta africana	African elephant	3	NA	0.64	NA	0.13	NA		
Mellivora capensis	Honey badger	4	11	0.86	2.45	0.2	0.47	2.5	0.106
Mungos mungo	Banded mongoose	NA	1	NA	0.22	NA	0.07		
Nandinia binotata	Palm civet	2	NA	0.43	NA	0.13	NA		
Nesotragus moschatus	Suni	98	51	21.03	11.36	0.8	0.6	61	0.090

Panthera pardus	Leopard	2	1	0.43	0.22	0.07	0.07	1.5	1
Papio cynocephalus	Yellow baboon	2	1	0.43	0.22	0.07	0.07	1.5	1
Paraxerus vexillarius	Tanganyika mountain squirrel	6	7	1.29	1.56	0.2	0.2	5	1
Petrodromus tetradactylus	Four-toed sengi	NA	2	NA	0.45	NA	0.13		
Potamochoerus larvatus	Bush pig	15	34	3.22	7.57	0.47	0.53	9	0.222
Syncerus caffer	African buffalo	1	NA	0.21	NA	0.13	NA		

Table 2 .Summary of the four dynamic occupancy models testing inter-season variation of six species of mammals that had high trapping events in the Udzungwa Mountains, Tanzania.

Species	Model[1]	Number of parameters	AIC	Delta	AIC weight	Cumulative weight
Bdeogale crassicauda	M0	4	272.26	0.00	0.063	0.62
	M1	5	274.22	1.96	0.234	0.86
	M3	7	277.80	3.53	0.039	1.00
	M2	6	275.84	3.58	0.104	0.96
Potamochaerus larvatus	M1	5	171.59	0.00	0.441	0.44
	M3	7	171.60	0.01	0.439	0.88
	M2	6	175.00	3.41	0.08	0.96
	M0	4	176.43	4.84	0.039	1.00
Cephalophus harveyi	M0	4	256.85	0.00	0.641	0.64
	M1	5	258.85	2.00	0.236	0.88
	M2	6	260.79	3.93	0.09	0.97
	M3	7	262.79	5.94	0.033	1.00

Species	Model[1]	Number of parameters	AIC	Delta	AIC weight	Cumulative weight
Nesotragus moschatus	M0	4	247.49	0.00	0.473	0.47
	M1	5	248.30	0.81	0.316	0.79
	M2	6	250.11	2.62	0.128	0.92
	M3	7	250.96	3.47	0.084	1.00
Cercocebus sanjei	M0	4	229.89	0.00	0.519	0.52
	M1	5	231.26	1.37	0.262	0.78
	M2	6	232.46	2.56	0.144	0.93
	M3	7	233.77	3.87	0.075	1.00
Cricetomys gambianus	M0	4	248.70	0.00	0.572	0.57
	M1	5	250.47	1.77	0.236	0.81
	M2	6	251.58	2.88	0.136	0.94
	M3	7	253.33	4.63	0.057	1.00

[1]M0=$\psi(.)\gamma(.)\varepsilon(.)p(.)$; M1=$\psi(.)\gamma(.)\varepsilon(.)p(\text{season})$; M2=$\psi(.)\gamma(\text{season})\varepsilon(\text{season})p(.)$ and M3 = $\psi(.)\gamma(\text{season})\varepsilon(\text{season})p(\text{season})$.

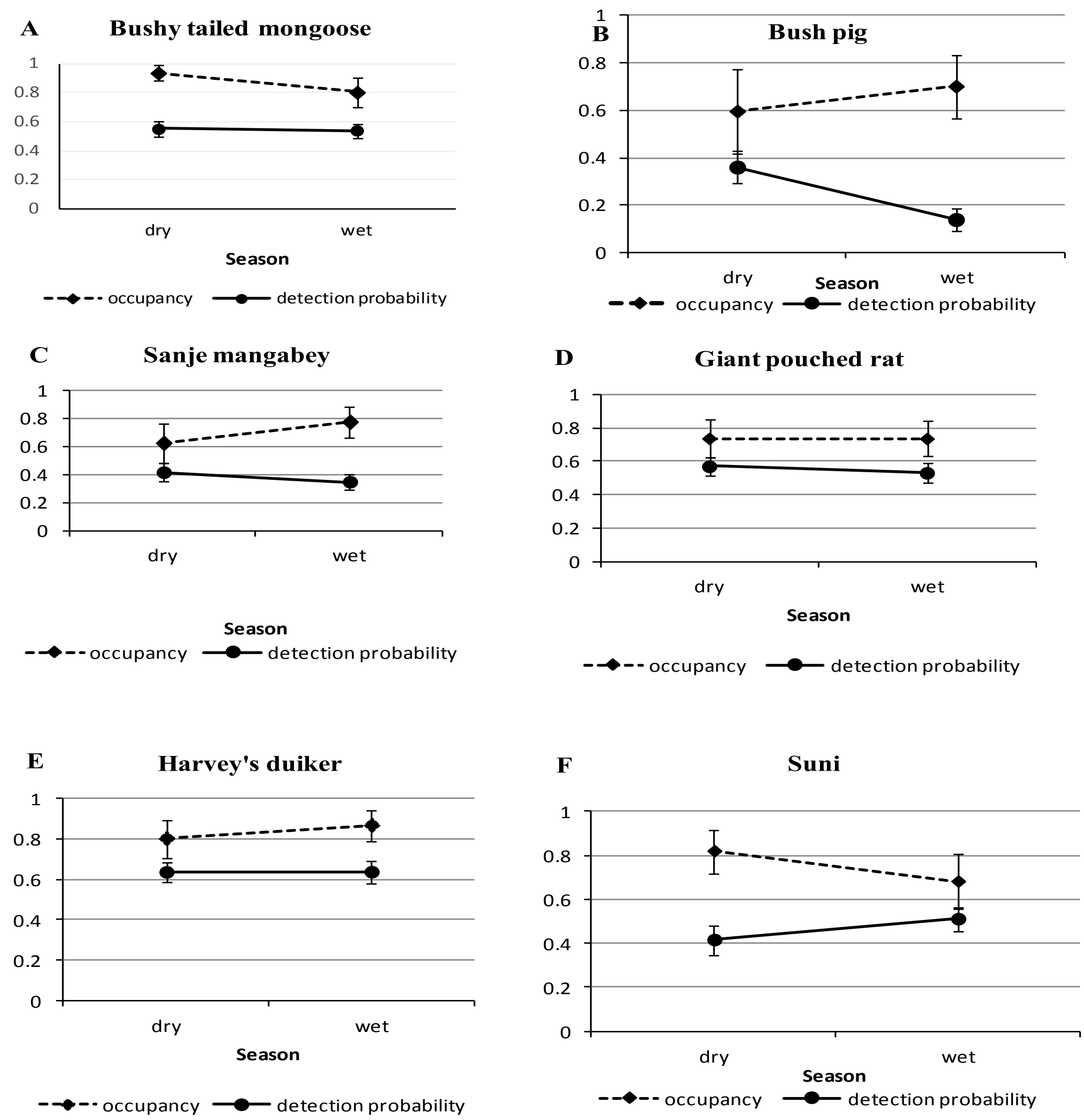

***Figure:2**: Plots of dynamic occupancy models with detection of the six mammal species with high trapping events (>10) in Mwanihana Forest, Udzungwa Mountains, Tanzania.*

DISCUSSION

We used camera trapping coupled with dynamic occupancy modelling to test whether seasonal variation had any effect on estimated occupancy and detectability of forest dwelling mammals in the Udzungwa Mountains of Tanzania. For the six species for which we had enough data, we generally found that neither occupancy nor detectability varied significantly between seasons, with the exception of bushpig for which detectability decreased significantly from dry to wet season. This result from a modelling approach that explicitly considers imperfect detection is concordant with the results from the comparison of raw data (i.e. RAI, an event rate index) for the 15 species that were detected in both seasons, whereby no significant differences emerged except for one species, the bushy-tailed mongoose.

This is, to our knowledge, the first study to address the effect of variations in rainfall in occupancy estimation in forest mammals, and the main result of a lack of major responses is interesting as in fact detectability may be influenced by a range of different factors, such as shyness and vegetation denseness (Rovero *et al.,* 2014a), and climatic conditions (Rowcliffe *et al.,* 2011). That occupancy too did not vary is perhaps less surprising as target species are resident, forest-dependent mammals and no major movements outside the sampled sites were expected. Changes in activity and movement patterns *within* the area sampled, which may be associated with seasonality and resource availability, may not be excluded, and may indeed explain the significant variation in detectability of the bush pig. For example, Mwamende (2009) found that Sanje mangabey in the same forest as our study moved more in dry than wet season possibly in response to sparser food availability, particularly fruits. However, these variations do not appear to influence the dynamic parameters of immigration/emigration and extinction/colonization that would affect the probability of occurrence.

The results have two important implications for the design of monitoring programmes that aim to determine population trends. First, it supports the choice of a discrete season to sample the population/s of interest over multiple years without need for accounting for the full spectrum of seasonal variations, which would likely imply logistic constraints and greater costs. This finding is mirrored by a study conducted in the same area that found that line transect-based detectability and estimated local abundance of arboreal primates did not change between wet and dry seasons, justifying the choice of sampling in the dry season only (Rovero *et al.*, 2015). Second, it supports the choice of dry season for easier implementation of camera trapping (TEAM Network, 2011). Indeed despite using tropicalized and professional camera traps, 25% of the camera units failed during the wet season while all worked fine in the dry season, a difference which is likely due to moisture accumulation on the camera trap sensor (Kays *et al.,* 2009) causing malfunctioning or blurred images (which may in turn prevent proper species identification).

In conclusion, we provided a first contribution on the effects of seasonal variation on occupancy and detectability of tropical forest mammals. Further assessments with larger sampling efforts and allowing for a broader range of species to be analyzed will help elucidating the consistence of our results. With the increasing use of camera trapping in a wide range of wildlife research applications (e.g. O'Connell, Nichols, & Karanth, 2011; Rovero *et al.*, 2013), including standardized monitoring programmes (Ahumada *et al.*, 2011; 2013), consideration of the potential sources of variations in the results will become of concomitantly increasing relevance.

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SEROPREVALENCE AND SPATIAL DISTRIBUTION OF RIFT VALLEY FEVER IN HUMANS IN AGRO-PASTORAL AND PASTORAL COMMUNITIES DURING INTER EPIDEMIC PERIOD IN THE SERENGETI ECOSYSTEM, NORTHERN TANZANIA

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ABSTRACT

Rift Valley Fever (RVF) is a global re-emerging viral zoonotic disease, affecting both humans and animals. The RVF outbreak in Tanzania of 2006/7 had a human case fatality rate of 46%, with thousands of livestock deaths. A cross sectional study on prevalence of RVF virus in the Serengeti ecosystem in 2012/13 found active circulation of RVF virus in mosquito vectors, wildlife and livestock. In 2014, sero-prevalence, spatial distribution and factors associated with RVF in at risk communities were determined to understand the disease status in humans in the same ecosystem. A hospital based cross-sectional study was also conducted in communities in the ecosystem. Sera from consented human subjects were tested for general exposure by detecting anti–RVF IgG and for recent infection by detecting anti–RVF IgM using ELISA. We conducted logistic regression for risk factors and mapped the hotspot areas for virus circulation. A total of 751 consented study subjects were enrolled at out-patient clinics with a median age of 35.5 years of which 58.5% were females. The proportion of human subjects that tested positive for IgG was 4.5% (95% C.I 3.2-6.3%). Of the 34 that tested positive for IgG, six (17.6 %) tested positive for IgM. Odds of exposure were higher in pastoral communities (aOR 2.9, 95% C.I: 1.21, 6.89, p <0.01), with exposure to both livestock and wildlife (aOR 1.8, 95% C.I 1.14, 3.39, p = 0.03). Hotspots for exposure to RVF virus were Malambo, Olbalbal and Piyaya wards in Ngorongoro district, and Lamadi ward in Busega district. High prevalence and detection of IgM suggest ongoing transmission of RVF in *humans and animals during inter epidemic periods. Agro-pastoral and pastoral communities with high interaction with livestock and wildlife are at risk of contracting the disease. Awareness creation to these communities may be useful in preventing future disease outbreaks.*

INTRODUCTION

Viral Haemorrhagic Fever (VHF) is a global re-emerging zoonotic threat with concern of international spread (IHR, 2005). Its case fatality rate range from 2% - 90% depending on the family of the virus in question (WHO, 2007). Rift Valley Fever (RVF) is one of VHF caused by genus *Phlebovirus* in the family *Bunyaviridae* (Caroline et al., 2014, Caminade et al., 2014, Kahlon et al., 2014) . It causes severe illness characterized by deaths and abortion storm primarily to goats, sheep, and cattle (CFSPH, 2013). Humans, wildlife and domesticated animals such as camels and dogs can also be infected (Joshua and Sallu, 2014).

In Tanzania, the 2006/7 RVF outbreak recorded a case fatality of 46%, and was even higher to 75% among HIV infected humans (Mohamed et al., 2007). It caused an estimated loss of more than $4 million to the government to control the disease. Death of animals due to the disease was estimated to cost around $6 million, with external market flow dropping by 54% (Sindato et al., 2007). Shortage of meat and milk probably caused acute malnutrition to children under-five years, pregnant mothers and elders. Most of the markets were closed and cost of alternative source of protein such as fish and chicken was very high (Chengula et la., 2013a, Sindato et al., 2007). In humans, RVF usually causes mild fever that is often associated with spontaneous recovery (Mohamed et al,. 2007, Chengula et al., 2013a). Few infections characterized by flue like illness, headache, muscles and joint pain, diarrhoea, vomiting; similar to malaria (Chipwaza et al., 2014) anorexia and high respiration rate (WHO, 2007). RVF may cause serious hepatitis and liver necrosis (Mohamed et al., 2007, Fyumagwa et al., 2011) as well as other complications including loss of eyesight, meningo-encephalitis and haemorrhagic fever (Mohamed et al., 2007, Fatetine et al., 2013, Shiel et al., 2010).

Despite the severity of the RVF, little is known regading transmission and exposure status of humans in different ecosystems in Tanzania. Previous study conducted at Kilombero valley in eastern Tanzania showed high transmission of the disease in livestock, with sero-prevalence of 5.5% among animals born after last epidemic of 2007 (Sumaye et al., 2013). Likewise, current data in the Serengeti ecosystem has found circulation of RVF Virus in livestock, wildlife and arthropod vectors (Nyarobi *et al*, unpublished). Wildlife is closely connected to tourism industry, a major source of revenue in Tanzania. The epidemic may affect the industry because of fear among tourists of contacting the disease, and loss of animal species that are sought for game viewing. Wild animals such as monkeys, African buffalo, black rhino, lesser kudu, impala, kongoni, waterbuck and African elephants have shown to be infected with the disease (Evans et al., 2008).

Following severe RVF epidemic of 2007, there was need to understand the current disease burden in humans and predict the possibility of future outbreak. Therefore, the objective of this study was to determine the exposure status of RVF, its spatial distribution and factors associated with exposure to RVF among pastoral and agro-pastoral communities of the Serengeti ecosystem. This was consistent with one health concept that need multisectoral partnership in adressing diseases with potential of infecting both human and animals to have great impact in adressing the disease problem during outbreaks.

METHODS AND METHODS

Study area and Population

The study area included three districts of Ngorongoro, Serengeti and Bunda in the Serengeti ecosystem, northern Tanzania (Figure 1). The ecosystem favours the endemicity of the RVF in the area. Large part of the area is in Serengeti National Park, Ngorongoro Conservation Area, Game Reserves (Maswa, Ikorongo-Grumeti) and Loliondo Game Controlled Area, and the communities surrounding it are mainly of pastoral and agro-pastoral communities. The study was conducted in the District Designated hospitals (DDHs) in each of the three districts, however because Ngorongoro district is sparsely populated, we included four dispensaries (Malambo, Piyaya, Arash and Olbalbal) and Endulen Hospital to increase the coverage.

Study design and setting

A cross-sectional, hospital based study was conducted on humans in the Serengeti ecosystem from August-October, 2014. We targeted outpatient department (OPD) patients >5 years regardless of their clinical presentation. Children below five years, admitted patients, those who refused to consent and those who were critically ill were excluded from the study.

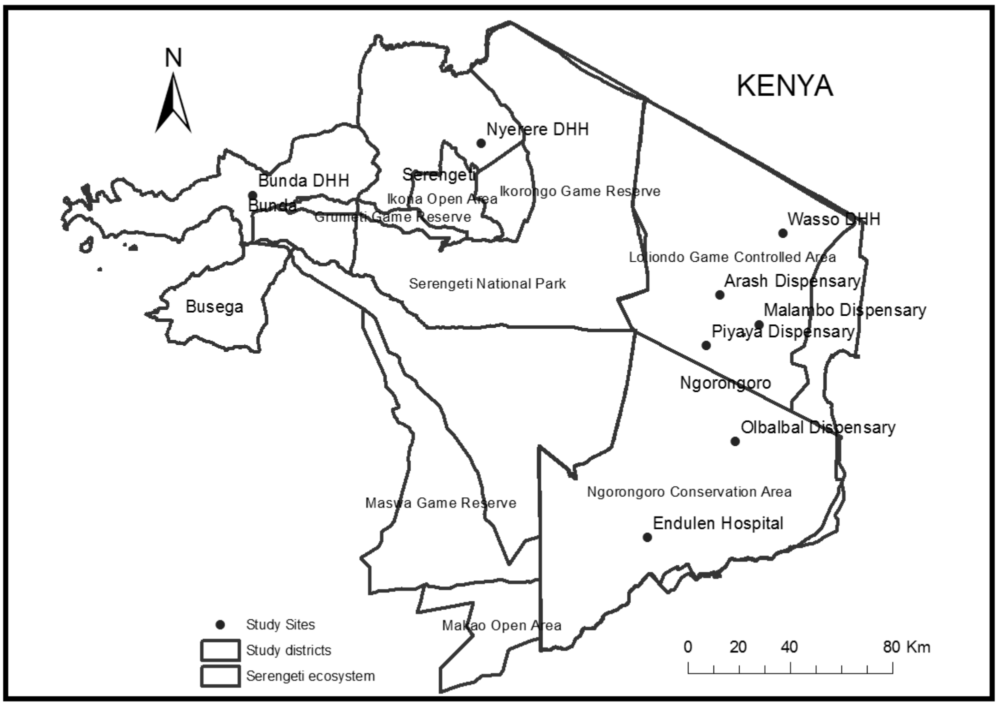

Figure 9: *Map of Serengeti ecosystem showing the Rift valley Fever study area*

Sample size and Sampling strategy

The required sample size was calculated using epi info 7 based on the estimated prevalence of RVF in humans of 4.0% (18) and at 95% C.I, the z-value is 1.96 and margin of error of 1.4%. Number of participants in each district was calculated based on the respective population size of the particular district. The estimated sample size was 750 human subjects and the weighted sample size per district was 210, 241 and 300 for Ngorongoro, Serengeti and Bunda districts respectively. Whole blood sample was taken from each respondent for subsequent preparation of serum and serological analysis.

Participants were selected by consecutive enrolment, in which all eligible patients who consented were enrolled, until the sample size was reached.

Data collection

About 2 ml of whole human blood was drawn from the consented patients in plain vacutainer tubes (4 ml) then, was centrifuged to obtain 1ml of serum, which was then frozen in screw capped cryovials and stored at -20^{0}C freezer for subsequent serologic analysis. Participant's characteristics including age, sex, area of residence, level of education and occupation were recorded.

Laboratory methods

Serum analyses

Analysis of samples for general exposure status (IgG) was done at Nelson Mandela African Institute of Science and Technology (NM-AIST), Tanzania, using kit for the detection of IgG anti –RVF – Nucleoprotein by competitive ELISA, RVF ID screen Rift Valley Fever competition multi-species (ID.Vet Innovative Diagnostics, Grabels, France). Similarly, detection of recent infection was done at National Health Laboratory Quality Assurance and Training Centre (NHL-QATC) in Dar es Salaam, Tanzania by using IgM capture ELISA kit, employed for all positive samples as described by the manufacturer (Biological Diagnostics Supply Limited -BDSL, UK).

Statistical analysis

We calculated median, range, and proportion of seropositive samples among those tested for IgG (general exposure status) and IgM (recent exposure status) against RVF virus. We performed bivariate analysis by calculating Odds Ratio to determine the association between outcome and exposures. We used Chi square test at 95% confidence interval to measure statistical significance between exposure status and outcome. All variables with p-value <0.05 in bivariate analysis were regarded as statistically significant. All variables with p-value less than or equal to 0.1 were entered into the multivariate logistic regression model. The final model was generated using stepwise backward elimination unconditional logistic regression and we considered variables with p-value <0.05 as significant. GPS positions from where data were collected were recorded and matched with respective seropositive humans, and represented in a spatial distribution map of study area.

Ethical consideration

We obtained written Informed consent from all study participants. The study was reviewed and approved by ethical committee of Muhimbili University of Health and Allied Sciences (MUHAS). Authority to conduct the study was obtained from Tanzania Wildlife Research Institute (TAWIRI), Ngorongoro Conservation Area Authority (NCAA), the respective District Councils and the Management of the respective health facility.

RESULTS

In total we enrolled 751 participants in this study. Their median age was 35.5 with range of 5-90 years. Of them, 439 (58.5%) were female, 294 (45.9%) were small scale farmers, 420 (63.8%) had primary education and 300 (40%) were coming from Bunda district (Table 1).

Table 1: Socio-demographic distribution of study respondents in the Serengeti ecosystem, 2014

Variable	No. Enrolled (Total 751)	Proportion Enrolled (%)
Age group		
<14	42	5.6
15-29	218	29.0
30-49	384	51.0
>50	107	14.3
Sex		
Female	439	58.5
Male	312	41.5
Districts		
Bunda	300	40.0
Ngorongoro	210	27.9
Serengeti	241	32.1
Level of education		
Informal	214	28.5
Primary	420	55.9
Secondary	98	13.1
College	**19**	2.5
Occupation		
Businessmen	70	9.3
Pastoralist	227	30.2
Peasant	294	39.2
Employed	49	6.5
Others*	111	14.8

** Those whose occupation was not specified during data collection*

Out of 751 participants tested for IgG, 34 tested positive making the overall IgG sero-prevalence of 4.5% (95% C.I 3.2-6.3%; Table 2). For recent exposure to RVF virus, of 34 positive IgG subjects, 6 (17.6%) tested positive for anti RVF

IgM. Ngorongoro district recorded high seroprevalence of anti RVF antibodies at 8.1%, (17 of 210) compared to 2.1% of Serengeti district (5 of 241) (P=0.003; Table 2). The seroprevalence of RVF was significantly higher among pastoralists (8.9%, 20 of 227) compared to farmers (3.4%, 10 of 294) (p=0.008; Table 2).

Table 2: Seroprevalence of anti RVFV IgG by demographic factors in the Serengeti ecosystem

Variable	No. Enrolled	No. of IgG +VE	%Seroprevalence	P value
Total	**751**	**34**	4.5	
Age group				
<29	249	11	4.4	Ref
30-49	383	16	4.2	0.61
>50	106	7	6.6	0.57
Sex				
Female	439	17	3.9	0.30
Male	312	17	5.5	
District				
Bunda	300	12	4.0	0.61
Ngorongoro	210	17	8.1	0.003
Serengeti	241	5	2.1	Ref
Level of education				
Informal	214	10	8.3	0.86
Primary	420	18	4.3	0.996
Secondary**	117	5	4.3	Ref
Occupation				
Bussinessman	70	4	5.7	0.36
Pastoralist	227	20	8.8	0.008
Others*	111	0	0	_
Employed	49	0	0	_
Peasant	294	10	3.4	Ref

** Those whose occupation was not specified during data collection*

*** Secondary include both with secondary and college education*

A number of risk factors for RVF, including age, sex, occupation, level of education, and district of residence where cases were coming from were assessed. The odds of testing positive was almost 3 times higher among the pastoralists as compared to other occupational groups (aOR 2.9, 95% C.I: 1.21 to 6.89, p <0.01; Table 3). Those respondents who came from Ngorongoro (pastoral communities) were 2 times more likely to test positive for RVF as compared to respondents from other districts (aOR 1.8, 95% C.I 1.14 to 3.39, p = 0.03; Table 3). Age, sex and level of education were not statistically associated with exposure to RVF (Table 3).

Table 3: Social demographic factors associated with RVF sero-positivity in the Serengeti ecosystem

Risk factor analysis	Outcome		cOR	95% CI	aOR	95% CI
	+ve	-ve				
Occupation						
Pastoralist	20	205	3.56	1.77- 7.19	2.9	1.21-6.89
Others*	14	512				
DISTRICT						
Ngorongoro	17	193	2.71	1.36- 5.42	1.8	1.14-3.39
Others	17	524				
Education						
High education	5	93	1.15	0.44- 3.06	N/A	
Low education	29	624				
Age group						
<29	11	249	0.91	0.44 - 1.89	N/A	
30+	21	470				
Sex						
Male	17	295	1.43	0.72- 2.86	1.5	0.75-3.03
Female	17	422				

** All other occupational groups combined*

The number of IgG seroposivity was highest in Malambo, followed by Olbalbal (Ngorongoro), Nyerere (Serengeti) and Bunda health facilities. The seropositivity of IgM was determined from IgG seropositive samples only. The seropositivity of IgM was sparsely distributed in Endulen, Piyaya, and Malambo in Ngorongoro district, as well as Bunda and Serengeti districts. Despite the higher IgG prevalence in Olbalbal, no anti RVF IgM was detected (Figure 2).

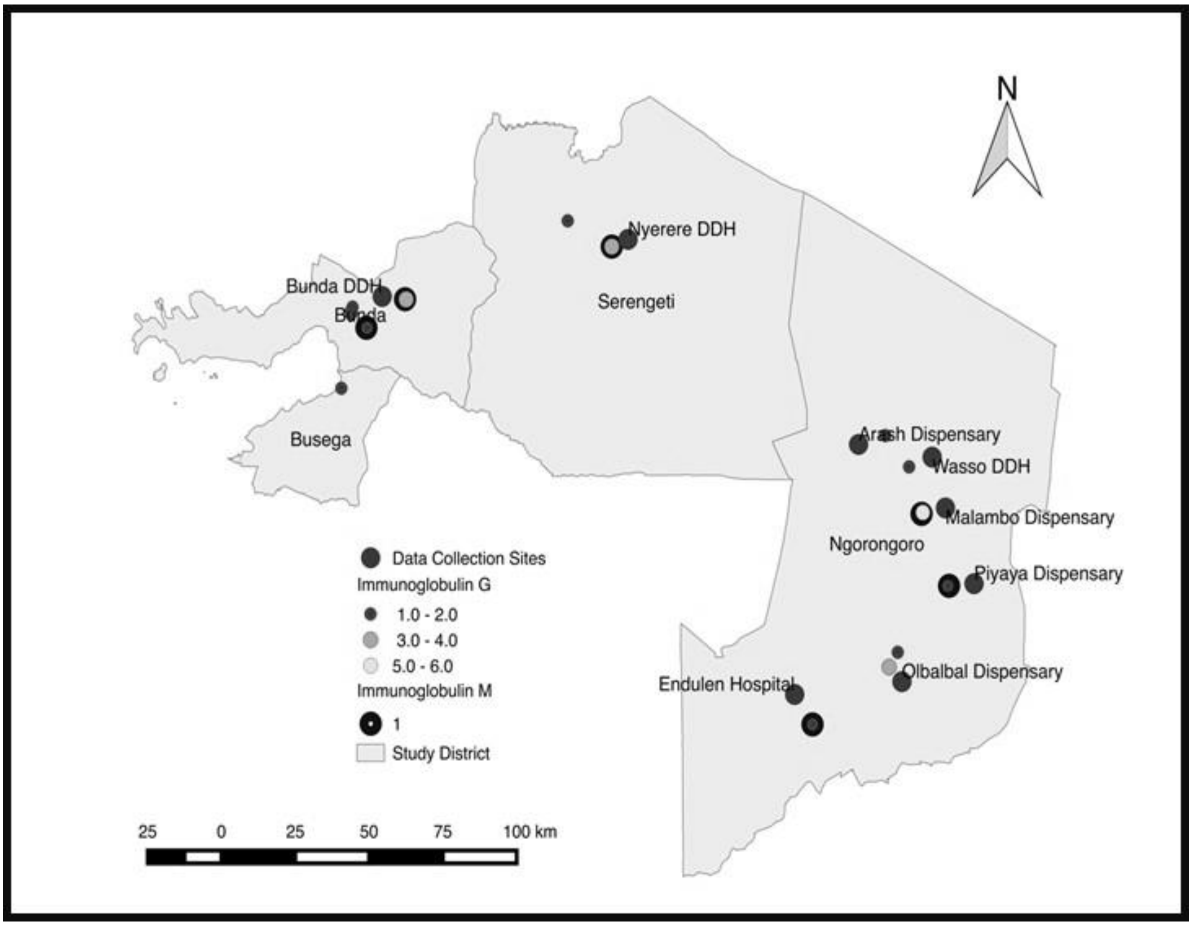

Figure 10: *Map of Serengeti ecosystem showing districts where anti RVF IgG seropositive humans were identified*

DISCUSSION

This present study shows past and recent exposure to RVF in the Serengeti ecosystem, as both IgG and IgM anti-RVF were detected. Nyarobi (unpublished) reported detection of RVFV nucleic acids in *Aedes* and *Culex* mosquitoes trapped in the Serengeti ecosystem, which together with our finding of RVF IgM, may indicate circulation of the virus during inter-epidemic periods. Living in Ngorongoro and being a pastoralist were the two main risk factors associated with exposure to RVF infection in our study.

The overall seroprevalence (4.5%) of RVF in the Serengeti ecosystem was slightly higher than what was previously reported in Tanga (4%) before the 2006/7 outbreak (Swai and Schoonman, 2009). The high prevalence in this study might be because of cumulative exposure to RVF disease in humans as well as increased infection among insects and animals, both domestic and wildlife. Detection of IgM among IgG seropositive humans was evidence that there is ongoing transmission of disease among humans. The ongoing transmission may be facilitated by the presence of competent vectors- *Aedes* mosquitoes. In addition, eating raw animal products, including meat, blood and milk is a common practice among the pastoral community living in the study area. The detection might also be due to exposure to infected animals and wildlife in the area. The recorded IgM seropositivity among IgG reactive samples is low compared to study done shortly after 2006 outbreak (Anyangu et al., 2007). However there are several studies that didn't find any IgM seropositive in spite of presence of IgG seropositive in both human (Swai and Schoonman, 2009) and animal (Joshua and Sallu, 2014). Large sample size may be useful to detect presence of IgM against the disease during inter-epidemic period especially in human.

The evidence of spatial distribution of cases in this study shows that Ngorongoro district had the higher seroprevalence, especially in Malambo, Olbabal and Piyaya villages, all of which are typical pastoral communities. In Bunda and Serengeti, most of the seropositive individuals were from the communities where agro-pastoral activities take place. The findings is in line with previous study, where number of clusters of RVF cases was found in several parts of Ngorongoro but neither in Bunda nor in Serengeti (Sindato et al., 2007). However, further research is needed to find out the reason behind this. It might be because of introduction of live animals and animal products from Ngorongoro to Bunda and Serengeti districts in search of market or pasture during drought. Some of the seropositive individuals in Bunda DDH were coming from Lamadi in Busega district, an area nearby to where RVF virus was recently found in mosquitoes Nyarobi et al., (unpublished).

Geographically, Ngorongoro district had the highest seroprevalence of RVF compared to Bunda and Serengeti districts. Large area of Ngorongoro district is sparsely populated and animal keeping is the main activity of the residents, as no cultivation is allowed in the area. The higher exposure rate in Ngorongoro district could be attributed by the 2006/07 RVF outbreak (Mohamed et al., 2007). High rainfall experienced in eastern side of the

Serengeti ecosystem, high temperature and soil texture supportive of flooding in Ngorongoro, and high animal density in the ecosystem may account for high disease prevalence in Ngorongoro. It is known that Rift Valley Fever virus once introduced in an area, continues to exist for decades as it is maintained by *Aedes* mosquitoes through vertical transmission.

In this study, pastoralists were more exposed to RVF with seroprevalence of 8.9% compared to other occupations (3.0%), which is in line with findings of other studies (Anyangu et al., 2007, Pourrut et al., 2010). This may be due to the fact that pastoralism is one of the major risk factors related to exposure to RVF virus by subjecting people to frequent contact to infected animals and consumption of animal's raw products such as blood, meat and milk. Increased exposure might be enhanced because of knowledge, attitude and practices (KAP) of the respective community. For instance, theMasai pastoralists keep their animals like sheep, goats and calves indoors during night to prevent them from wild carnivores' attack (Chengula et al., 2013b). Age, sex and level of education were not statistically associated with exposure to RVF infection.

The study was conducted in the Serengeti ecosystem, which has experienced several outbreaks of Rift Valley Fever disease previously (Sindato et al., 2007; Nyarobi et al. 2013, unpublished). Thus the findings may have limitation in generalization to other area of Tanzania. Likewise, as the study was cross-sectional in nature, it can only determine relationship at point in time and hence cannot determine temporal relationship. The study was done as hospital based because of time limitation and financial constraints. The findings from this study can be used as an estimate of RVF seroprevalence in the Serengeti ecosystem, however, hospital based study might have some bias and therefore it could be better if it were to be done as community based study.

CONCLUSION

The study found both previous and recent exposure of RVF in humans residing in the Serengeti ecosystem as antibodies against both IgG and IgM were detected. Ngorongoro district, where there is high human-animal interaction, both domestic and wildlife was most exposed to RVF compared to Bunda and Serengeti districts. Therefore, the risk of exposure to RVF virus was high among pastoral communities compared to farming communities and town dwellers.

RECOMMENDATIONS

The government should alert the community members, particularly pastoral communities on the current disease status so that they can take necessary precaution against the disease, as they are at high risk of exposure to disease than any other occupation in this study. Since RVF is more prevalent in Ngorongoro compared to Bunda and Serengeti, the district has to conduct special campaign to encourage hygienic practice in animal keeping and use of meat and other animal products, so that animal to human transmission can be controlled.

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STATUS OF BRUCELLOSIS IN BUFFALOES AND CATTLE IN SELECTED ECOSYSTEMS IN TANZANIA

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ABSTRACT

Brucellosis is a bacterial disease of economic and conservation significance, which causes infertility in livestock and has also been reported to cause infertility in wildlife. There are many species of the bacterium; however, Brucella abortus, B. melitensis and B. suis all have clinical impacts, primarily as a cause of reproductive losses. In animals, brucellosis is transmitted through ingestion of contaminated pasture and water from infected post-parturient discharges and suckling of infected milk in new born calves, and during mating. In humans the disease is likely to be transmitted through drinking unpasteurized milk, consuming raw blood and meat and by handling fetal membranes or fetuses while assisting calving animals during difficult birth. However, the relative importance of these different transmission routes is still uncertain. A sero-survey using Rose Bengal Plate Agglutination Test indicated that 20%, 10%, 26%, 10.7%, 7.7%, 17% and 24% of buffaloes were sero-positive for Brucella abortus in Arusha, Katavi, Mkomazi, Mikumi, Ruaha-Rungwa, Selous and Tarangire ecosystems respectively. The exposure status in indigenous cattle was 5%, 10%, 12%, 23.7%, 11% and 14% in Katavi, Kigosi-Moyowosi, Mkomazi, Mikumi, Ruaha-Rungwa and Selous ecosystems respectively. These results suggest that the disease is established in susceptible wildlife in many protected areas and is endemic in livestock in Tanzania. Levels of infection in buffalo were higher in many ecosystems as compared to livestock, but the impact of infection on buffalo health and reproduction in these ecosystems is not yet known. Since the RBPT has a low sensitivity compared to ELISA test, the actual disease problem might be higher than the prevalence found in this study. Given the lack of coordinated disease prevention and control in livestock, brucellosis is likely to pose a widespread risk to human and animal health in Tanzania. The frequent misdiagnosis of *human cases of brucellosis, often as malaria, demonstrates the urgent need for improved diagnostic testing of people presenting with non-specific febrile illnesses. cxMoreover, linked human and animal sampling should be conducted in endemic areas in order to determine the disease burden in humans as well as some aspects of transmission pathways at the human-livestock-wildlife interface.*

Keywords: brucellosis, livestock, wildlife, zoonosis

INTRODUCTION

Brucellosis is a re-emerging zoonosis caused by intracellular microorganisms *Brucella* spp primarily affecting livestock, wildlife and humans worldwide (Godfroid, 2002; Godfroid et al., 2005; Beja-Pereira et al., 2009; Olsen, 2013). The bacteria cause reproductive losses in livestock and wildlife, and is clinically characterized by one or more of the following signs: abortion, retained placenta, orchitis and epididymitis, with excretion of the organisms in semen, uterine discharges and milk (Fyumagwa et al., 2009; Godfroid et al., 2010; Godfroid et al., 2013; Olsen, 2013). *Brucella* spp of importance include *B. abortus, B. melitensis* and *B. suis*, and occurrence of the disease in humans depends largely on the occurrence of brucellosis in an animal reservoir, including wildlife (Godfroid et al., 2013; Olsen, 2013).

Although *Brucella* spp are named according to their preferred hosts – *B. melitensis* (sheep and goats), B. suis (swine), *B. abortus* (cattle) and *B. ovis* (sheep), some pathogenic species of *Brucella* have been isolated from other host species including *B. suis* isolated from cattle and reindeer (*Rangifer tarandus*); *B. melitensis* isolated from cattle, water buffalo (*Bubalus bubalis*), camels (*Camelus dromedarius*) and an Iberian wild goat (*Capra pyrenaica*); and *B. abortus* isolated from camels, water buffalo, bison (*Bison bison*), feral swine, elk (*Cervus elaphus*) and other species of cervid (Olsen, 2013). Infection is through invasion of the mucous membranes of the oropharynx, upper respiratory tract, conjunctiva, damaged skin and genital organs (Godfroid et al., 2010). However, the major route in natural infections appears to be the oropharyngeal route. In humans, symptoms such as undulant (rising and falling) fever, tiredness, night sweats, headaches and chills may drag on for as long as three months before the illness becomes so severe and debilitating as to require medical attention (Godfroid et al., 2013). The bacteria occasionally localize in joints or other tissues leading to osteoarthritic or necrosuppurative lesions (Olsen, 2013). Spill over infection from livestock to wildlife and spill back to livestock from sustained infection in wildlife is not uncommon (Garin-Bastuji et al., 2000; Beja-Pereira et al., 2009). Livestock keepers, laboratory and animal health workers are most frequently infected (Martin-Mazuelos et al., 1994; Brew et al., 1999; McDonald et al., 2006; Pappas et al., 2006).

Food-borne zoonoses are major health problem in developing countries due to little knowledge on the epidemiology of these diseases. The attitude and practices among community members towards disease prevention and control is largely influenced by the availability of food, water and source of energy. Brucellosis control in most developing countries is not a priority due to limited information on the extent and economic impact of the disease problem. Poor economies hinder concerted effort to conduct comprehensive disease surveillance to establish the disease prevalence countrywide (Fyumagwa, 2010). Extensive livestock husbandry system, open livestock market and communal land tenure system are exacerbating disease transmission from one livestock population and from one location to another (Bugwesa et al., 2009). Poor veterinary services including disease diagnosis, prevention, control and free livestock movement pose a risk to disease spread and re-emergence even in areas where it was controlled in the past (Godfroid et al., 2005; Seleem et al., 2010).

In Tanzania, there is little information on the status of brucellosis in livestock and wildlife due to lack of resources to conduct cross-sectional surveys in all the ecosystems. Although the disease is notifiable worldwide (Godfroid et al., 2010), the knowledge, attitude and practices among livestock keepers in Tanzania with regard to the epidemiology of brucellosis is very low, exacerbating risk for people to contract the infection.

The objective of this retrospective survey was to establish disease prevalence at the livestock-wildlife interface in the selected ecosystems in Tanzania.

MATERIALS AND METHODS

Study area and source of samples

The study was conducted in cattle (*Bos indicus*) and buffaloes (*Syncerus caffer*) in seven ecosystems including game reserves and national parks for buffaloes, and livestock in interface areas (Figure 1). Serum samples from buffaloes and cattle collected in a cross-sectional study for foot and mouth disease (FMD) surveillance by SADC-TADs and BBSRC projects from 2010 to

2013 were used for the sero-survey against *Brucella abortus*. For buffaloes the sample were collected from seven protected areas including Arusha National Park (n=26); Katavi National Park (n=29); Mikumi National Park (n=28); Selous GR (n=24); Mkomazi National Park (n=23); Ruaha National Park (n=39) and Tarangire National Park (n=25). For cattle the samples were available for serological analysis from six ecosystems including Katavi (n=39); Mikumi (n=38); Mkomazi (n=50); Kigosi-Moyowosi (n=30); Ruaha (n=27) and Selous (n=29).

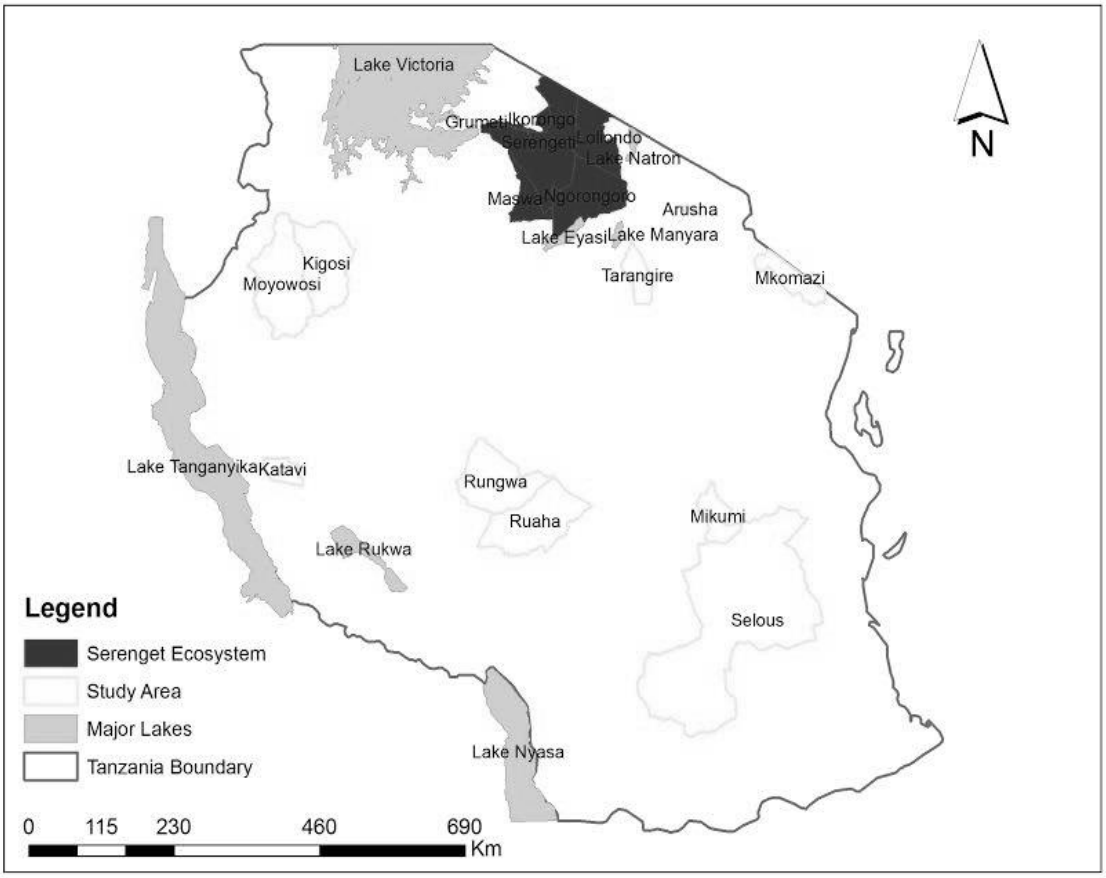

Figure 1: *Ecosystems where buffalo and cattle samples were collected for brucellosis sero-survey*

Serological analysis

A Rose Bengal Plate Agglutination Test (RBPT) (Standardized *B. abortus* Rose Bengal Plate Test Antigen, PA0060 Batch 266, Veterinary Laboratories Agency, New Haw, Addlestone, Surrey KT15 3NB, UK), a qualitative procedure involving visual assessment of agglutination of serum on glass slides was used to determine the serum samples which were sero-converting against *Brucella abortus*.

Data analysis
Descriptive statistics including prevalence, mean and standard deviation were used to analyse the data and Student t-test was used to determine the statistical significance at p=0.05 (Petrie & Watson, 2004).

RESULTS

In all the ecosystems the screened samples showed a varying degree of exposure to the bacterium both in buffalo and cattle. The sero-prevalence for buffalo from the seven ecosystems were 20% (Arusha); 10% (Katavi); 10.7% (Mikumi); 26% (Mkomazi); 7.7% (Ruaha), 17% (Selous) and 24% (Tarangire), and the overall mean prevalence in the seven ecosystems for buffaloes was 16.5±7.2% (SD). The sero-prevalence in cattle in six interfaces was 5% (Katavi); 10% (Kigosi-Moyowosi); 23.7% (Mikumi); 12% (Mkomazi); 11% (Ruaha) and 14% (Selous), and the overall mean prevalence was 12.6±6.2% (SD). The difference in mean prevalence in buffaloes and cattle were not statistically significant (p>0.05). Buffalo samples were not available in Kigosi-Moyowosi, while cattle samples were not available from Arusha and Manyara-Tarangire ecosystems. The number of animals screened and prevalence for buffaloes and cattle are summarized in Table 1. The comparison in prevalence for buffaloes and cattle in the respective ecosystems are shown in figure 2.

Buffalo samples were not available from Kigosi-Moyowosi Game Reserves due to failure to immobilize them as a result of increased human activities in these protected areas, and cattle samples were not available from Arusha and Tarangire ecosystems for inclusion in the analysis.

Table 1: Number of sero-positive samples and prevalence from buffaloes and cattle in all eight ecosystems

S/N	Ecosystem	Buffaloes			Cattle		
		+ve	-ve	Prevalence %	+ve	-ve	Prevalence %
1	Arusha	5	20	20	-	-	-
2	Katavi	3	26	10	2	37	5
3	Kigosi-Moyowosi	-	-	-	3	27	10
4	Mikumi	3	25	10.7	9	29	23.7
5	Mkomazi	6	17	26	6	44	12
6	Ruaha-Rungwa	3	36	7.7	3	24	11
7	Selous	4	20	17	4	25	14
8	Tarangire	6	19	24	-	-	-

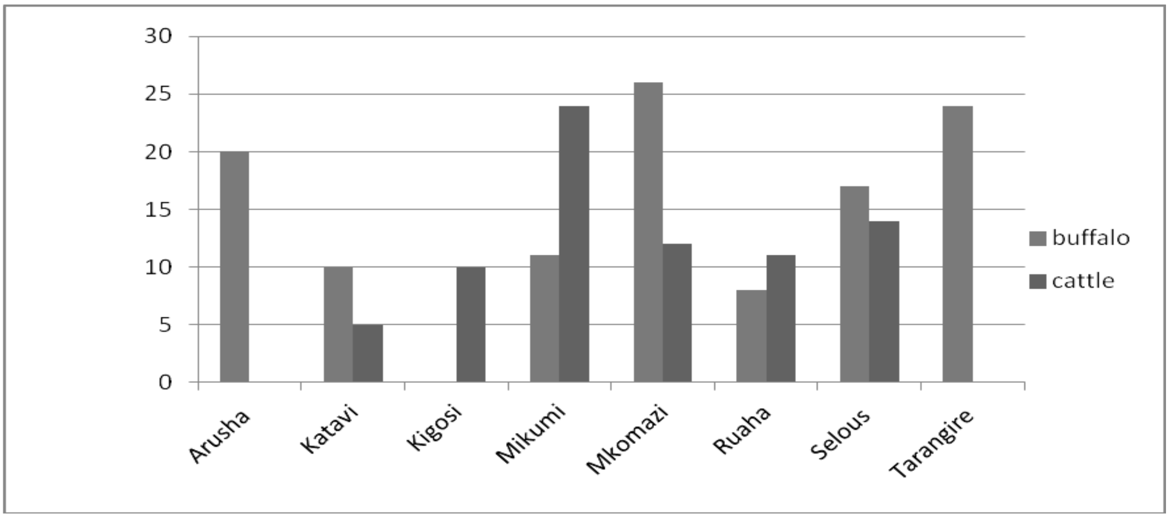

Figure 2: *Comparison of brucellosis prevalence between buffaloes and cattle in the interfaces*

DISCUSSION

This cross-sectional retrospective sero-survey has revealed that both buffaloes and cattle in the ecosystems are exposed to the bacterium (*Brucella abortus)* with varying degrees. The relatively low sero-prevalence in some of the ecosystems is probably due to the fact that the qualitative method used (RBPT) is less sensitive compared to competitive ELISA (Godfroid et al., 2010). However, in a separate study in the Serengeti ecosystem the serological tests in a serial analysis, the RBPT results were similar to C-ELISA (Fyumagwa et al., 2009). On the other hand, the OIE recognizes and has prescribed RBPT as one of the standard screening tests because it is simple and more sensitive than Serum Agglutination Test (SAT) (Greiner et al., 2009; Godfroid et al., 2010). For Tanzania situation, in order to have valuable epidemiological information that allows tracing of infection back to their sources in areas where several biotypes co-circulate, biotyping is the best approach (Godfroid et al., 2010). In addition, fingerprinting methods such as multiple locus variable analysis (MVLA), which measures the number of tandem repeats at a given locus and multi-locus sequence analysis (MLSA) can differentiate isolates within a given biovar (Godfroid, 2002; Le Fleche et al., 2006; Maquart et al., 2009; Whatmore, 2009).

In livestock in the Serengeti ecosystem the sero-prevalence of *Brucella abortus* has been reported to be 8%, 11% and 14% in Ngorongoro Conservation Area, Bunda and Serengeti districts respectively (Bugwesa et al., 2009). The sero-prevalence in wildlife in the Serengeti ecosystem is 22% and 17% in buffalo and wildebeest respectively (Fyumagwa et al., 2009). In northern Tanzania, the infection in wildlife was hypothesized to be sustained from previous spillover infection from livestock. However, in the present study in southern Tanzania where livestock has only been introduced 6 years ago has revealed presence of high prevalence of infection in buffaloes of about 17% as compared to 14% in livestock (Figure 2). This observation suggests that probably there are different *Brucella* spp biotypes circulating independently in wildlife and is actually posing a risk of spillover infection to newly introduced livestock in the area. Therefore, the infection seems to be endemic in livestock and established in wildlife in many ecosystems due to high livestock-wildlife interaction (Bugwesa et al., 2009).

Lack of routine livestock vaccination to control the disease in agro-pastoral and pastoral communities and the communal grazing system favors transmission of the disease to naive susceptible population. In many developing countries brucellosis is reappearing due to poor economies and poor veterinary services (Godfroid et al., 2005; Seleem et al., 2010). In Tanzania, the Government withdrew from the delivery of veterinary services was left into private practice in mid 1990's, the Government remained with regulatory services and handling of trans-boundary diseases. This decision made many livestock keepers unable for to conduct routine veterinary services including vaccination of many zoonotic diseases due to high cost. When veterinary service was a public good, the government was providing subsidized services (Fyumagwa, 2010). In recent years there have been extensive uncontrolled livestock movements from Lake Zone and southern highlands to Rukwa ecosystem and southern Tanzania adjacent to Selous ecosystem. The uncontrolled livestock movement in the interfaces in Tanzania amid presence of free ranging wildlife is a risk for disease spill-over and spill-back among livestock, wildlife, and people.

From the descriptive statistics it can be extrapolated that about 3 million cattle are affected (12.6%) and 19 million cattle are at risk in the entire country. The relatively low overall prevalence in cattle (12.6±6.2%) compared to buffaloes (16.5±7.2%) is probably due to the fact that infertile cattle are often culled by selling them for slaughter, and the general lifespan of cattle is far more lower compared to buffaloes. Apart from long lifespan, buffaloes are not systematically culled by human based on fertility status as in livestock, and even trophy hunting or predation or poaching is by chance. With the exception of samples collected in Arusha and Tarangire National Parks which consisted of sub-adult and adult buffaloes, the samples from the remaining five protected areas consisted of juvenile and sub-adult buffaloes only

(1.5-3years). Therefore, the observed sero-prevalence is mainly from recent exposure to the bacterium.

The disease is mainly occupational in humans (abattoir, animal industry, hunters and health workers) but transmission through consumption of raw milk and milk products remains important in developing countries (Godfroid et al. 2013; Olsen, 2013). Similarly, many agro-pastoral and pastoral communities drink unpasteurized milk and eat medium cooked meat, and have little knowledge on the epidemiology of the disease exacerbating the risk of contracting this food borne zoonosis (Fyumagwa et al., 2009). In a recent study it has been established that 13.3% and 30.1% of the Maasai pastoralits eat raw meat and unpasteurized milk respectively (Keyyu et al., 2012). Given that the prevalence of disease is very high among indigenous cattle, poor knowledge on the epidemiology of the disease is a risk for contracting brucellosis. Hence, addressing the disease in natural hosts of *Brucella* spp is the most cost-effective mechanism to prevent human infections (Pappas et al. 2006; Godfroid et al., 2010; Olsen, 2013).

CONCLUSION

Given the lack of coordinated disease prevention and control in livestock, brucellosis is likely to pose a widespread risk to human and animal health in Tanzania. The frequent misdiagnosis of human cases of brucellosis, often as malaria, demonstrates the urgent need for improved diagnostic testing of people presenting with non-specific febrile illnesses. Moreover, linked human and animal sampling should be conducted in endemic areas in order to determine the disease burden in humans as well as some aspects of transmission pathways at the human-livestock-wildlife interface.

RECOMMENDATIONS

1. From the wide spread nature of the disease, we recommend that in addition to malaria and typhoid fever, medical services should embark on routine testing for brucellosis in patients presenting with undulating fever and generalized pain.
2. DNA detection by PCR and isolation of the bacterium are recommended to confirm and trace the origin of the infection in livestock and wildlife.

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AN OVERVIEW OF ENVIRONMENTAL DATA AND DATA OWNERS IN THE COASTAL AREA OF TANZANIA – AN EMERGING ENVIRONMENTAL SPATIAL DATA INFRASTRUCTURE

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ABSTRACT

Environmental data management is a crucial part of any decision making related to the local, regional, national and global aspects of the environment. Several studies indicate that traditional policies for data management, or lack thereof, are obstructing the development of adequate responses to rapidly expanding human economic activity. Infrastructure development is one such activity. Lack of such information or the coordination thereof can have impacts on wildlife management, both terrestrial and marine. The National Environment Management Council (NEMC) in Tanzania has, together with the Norwegian Environment Agency (NEA), taken steps to establish an overview of coastal environmental information. This paper describes the results of a survey made by the consulting company COWI Tanzania in April to July 2015. Through contact and interviews with 41 institutions, we have documented available data sets with subject, categories, access restrictions, formats and more. We have also mapped the institutions' willingness to contribute to a national environmental information network (EIN). Management of environmental information in Tanzania has so far not been coordinated using standards for exchange of data or registration of metadata. Nor has there been any centralized effort to establish standardized open access registries of environmental information. Based on interviews and advice from UNEP a way forward for establishing a shared data infrastructure for

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environmental in formation in Tanzania is proposed. Consequences for wildlife management and the land use planning are described.

Key words: data management, EIN, GIS, NSDI, SDI

INTRODUCTION

Oil and gas development in Tanzania goes back to 1952 with the drilling of the Songo Songo gas field in 1974 as the earliest economically important development. Over the last ten years, several areas were licensed to commercial partners (Tanzania Petroleum Development Cooperation, 2015).

The Norwegian directorate for development Cooperation (NORAD) funds a program coined "Oil for development" (NORAD, 2014). In March 2012, the Government of Tanzania and the Norwegian Ministry of Foreign Affairs signed a Programme Agreement. One of the activities under this agreement is to support an increased capacity for environmental management (Governments of Tanzania and Norway, 2012). A workshop on environmental data management in Tanzania arranged by NEMC and NEA pointed to the need for a national overview of coastal environmental information (Larsen, 2014).

A report on coastal environmental data (COWI Tanzania, 2015) and a process supporting the development of an environmental information network are two of the outcomes from this process. In the short term these contribute to the development of Tanzania's coastal environmental atlas, and in a longer perspective towards revising the currently available coastal sensitivity atlas (Samaki Consultants 2011; IPIECA 2012).

By law NEMC shall ".establish and operate a Central Environmental Information System which may bring together any findings, data and statistics generated by both public and private institutions in the course of environmental observation and management." (Tanzania, 2004).

To move towards a national overview and coordination of environmental information we asked the following questions:

- Is the available spatially referenced environmental information relevant for environmental management?
- Are the data presented with metadata?
- Are the respondents ready to share data as part of an environmental information network?

A short evaluation of the National Spatial Data Infrastructure in Tanzania will be used to give the findings a necessary context.

Scope and definitions

The geographical scope of this study covers districts in Tanzania with a coastline, the coastline itself and coastal and marine areas. Stakeholders contacted were governmental agencies, research institutions, non-governmental organisations (NGOs) and others. A shortlist of institutions was based on the EIN workshop in October 2014.

Environmental data/information in this respect include spatial data files, reports containing tables and maps, Excel sheets, data collection method descriptions, etc. It is not restricted to ecological/biological data, but can also be other relevant data (e.g. infrastructural, bathymetrical, meteorological, pollution and socio-economic data, etc.). Spatial data can be understood as data that indicates geographic information related to features and boundaries on Earth, such as natural or constructed features, oceans, or similar. Metadata is information that describes key characteristics of some original data, e.g. its content, conditions or locations.

Spatial Data Infrastructure (SDI) is a system for indexing data through metadata that enables users to describe or understand the scope, type or relevance of the original data as well as sharing the data. A National SDI is an implementation of legal structures, agreements, working procedures and systems.

Spatial data infrastructures in Tanzania

The missing NSDI in Tanzania

The development of a spatial data infrastructure is an essential requirement for sustainable development. Not only within one discipline, but also across disciplines and organizations (Feeney, Rajabifard, & Williamson, 2001).

It was revealed that many government offices, organizations and companies in Tanzania struggle with the different aspects of collecting, storing and disseminating their own information. Environmental data management is a crucial part of any decision making related to the local, regional, national and global aspects of the environment. Good quality, up-to-date, accessible and relevant information is the foundation of good decision making in governments. Likewise, emergency response systems rely on sound information about sensitive areas and resources.

According to Johansson (Johansson, 2006) the Tanzanian NSDI initiative began in 2003 with a two-day workshop held by the National Bureau of Statistics. While the initiative was carried forward through several meetings, and the partners discussed a division of responsibilities - this did not conclude with clear responsibilities. Resulting initiatives seem to have been both fragmented and insufficient in their structures and extent.

In a more recent paper (Lubidaa, Pilesjöa, Esplingb, & Runnströma, 2014) based on findings from a questionnaire sent to GIS professionals, predominantly within district GIS offices and some national level institutions, one of the more important findings point to the fact that:

"[..] a majority of the respondents expressed concern over the low capability of many institutions to collect and manage geographic data in order to cater for the growing demand for geospatial data."

Their respondents supported this, indicating the following:
A majority of the responses (79%) showed awareness creation as the main issue to be taken into consideration, while 72% showed lack of policy on the subject matter. Other comments are related to training of staff, storage, and updating issues, as well as the need for a lead organization to oversee SDI implementation.

Apart from working on the capacity to collect and store data, it is fundamentally important to establish or acknowledge systems and legal basis for sharing environmental data. The same way a SDI can support intra national initiatives it can also support initiatives across borders – to neighbouring countries as well as global. The INSPIRE directive (European Commission, 2007) in the European Community is an example of international collaboration for the purpose of standardizing and sharing spatial data.

Recent studies in Tanzania (Mansourian, Lubida, Pilesjö, Abdolmajidi, & Lassi, 2015) points to how a SDI can be developed in Tanzania. We believe that the way forward is to start work on an environmental spatial data infrastructure.

Environmental Spatial Data Infrastructure
One of the areas chosen for collaboration under the Oil for Development program was data management. In this work, it became clear that efforts to establish a sound knowledge basis for emergency response systems as well as

regional level decisions on petroleum related activities would require a better coordination of environmental information.

The 21st to the 23rd of October 2014 a workshop on data sharing was held at the Giraffe Ocean View Hotel in Dar es Salaam (Larsen, 2014). It was organized by NEMC in collaboration with the NEA. A representative from the Environmental Protection Agency in Ghana also contributed to the workshop.

The purpose of the workshop was to raise awareness on environmental data management and discuss a way forward towards national level coordination of environmental data and data management.

The role of the NEA in this workshop was to contribute to this process through the facilitation of discussions, presentations and dialogue with the participants. The participants were representatives from owners and users of environmental data in Tanzania. The Norwegian Oil for Development project funded the workshop.

The African EIN initiative was the outcome of the Africa Environment Outlook preparation process mandated by the African Ministerial Conference on Environment (AMCEN). It is supposed, "strengthen the capacity of African countries to use good quality information on environmental assets to make informed investment choices at national and sub-national levels, and manage these assets on a sustainable basis. A key objective of the initiative is to build capacity for establishing the essential data foundation needed to support country-level sustainable development initiatives, focusing on the environmental aspects." (UNEP, 2004)

The 11th AMCEN session was held in Brazzaville (Congo) the 22-26th of May 2006. It put forward a request to UNEP in which it called for the development of an Africa Environmental Information Network.

NEMC is the national focal point for the Tanzanian node of the African EIN. In discussing the collaboration between NEA and NEMC the conclusion was that the establishment of a Tanzanian EIN would be relevant. Support to this decision was among others based on positive developments in Uganda where the Uganda EIN had led to among several processes and products an Environmental Sensitivity Atlas for The Albertine Graben (NEMA, 2010). This initiative supports the intentions stated in the national environmental regulation 172-174 (Tanzania, 2004).

A survey on environmental data

Following up the EIN workshop of 2014, NEMC and NEA agreed that an appropriate way forward would be to establish an overview of existing information in the coastal areas of Tanzania. This would support a planned revision of the coastal sensitivity atlas as well as a coastal environmental atlas.

COWI Tanzania was asked to undertake a study to establish an overview of available environmental data throughout the coastal region and marine areas of Tanzania.

The deliverables from the assignment should provide:

- A list of all visited and all contacted stakeholders;
- A list of existing coastal and marine data, gaps in this data and data gathering projects;
- Information about the datasets or documents, with a special focus on coastline and mangrove datasets, documented in an Excel sheet designed by the Consultant in collaboration with NEA. The information includes geographical extent, categories, custodians and owners;
- Where possible, additional information about source for data and a brief note about accessibility;
- A description of metadata attributes according to the provided category system and, where possible, ISO/TC 211 and ISO 19115 2003;
- Indication of the stakeholder willingness and ability to contribute to a collaboration under the Environmental Information Network with their data;
- An overview of current developments/status related to a national spatial data infrastructure in Tanzania;
- Suggestions for further work; and
- A presentation at a marine data workshop, to be held back-to-back with a workshop discussing a possible coastal sensitivity atlas.

METHOD

The Consultant applied various methods to extract the information for this report. These include continuous dialog and fixed meetings with relevant institutions as well as a specially designed questionnaire tool. The questionnaire tool was designed in Excel to record types of information from stakeholders: the first type was information about stakeholders` attitudes, opinions or needs which could be relevant for the project, the other type was information about the institution`s possession of data that could be valuable for a SDI. The Excel questionnaire was designed with two sheets, each corresponding to these categories. This report refers to the sheet for data on stakeholder attitudes, opinions or needs as the institutional sheet (see Appendix A) the second as the dataset questionnaire (Appendix B).

FINDINGS

Contact was established with 41 institutions, most of which were physically visited. 26 institutional data sheets were completed. 16 dataset questionnaires were at least partly completed.

Table 1: Total and thematic numbers of coastal and marine dataset referred to by stakeholders

Theme	Academia	Government	NGOs	Private Sector	Other	Total
Biological	17		10	7		34
Socio-economic	7	16	5			28
Ecological	7	1	11	2		21
Meteorological		15				15
Fishery &		12	3			15
Protected areas	2	10		1		13
Infrastructural	11					11
Boundaries	7					7
Hydrological	1	5				6
Shipping		6				6
Topographical	4		2			6
Bathymetric	1		2	2		5
Cultural		1	2			3
Other		2			1	3
Recreation	2					2
Elevation	1					1
Waterways	1					1
Total	**61**	**68**	**35**	**12**	**1**	**177**

Out of the 144 coastal and marine datasets for which details stakeholders provided, 34 were placed under more than one thematic category. This implies that when all databases are listed per category, the total sum of databases corresponds to 177 (Table 1). The greatest number of datasets is within the biological theme (34 datasets), mostly held in academic institutions. Datasets defined as socio-economic rank second in terms of numbers recorded (28) with 21 potential overlapping datasets among the ecological theme. Again, most are held in government institutions. Fisheries and aquaculture, and meteorological, are themes for which 15 datasets are compiled for each, mostly held in government hands, followed by protected areas (13), where there were 10 recorded datasets under government jurisdiction, two under academia, with one under private sector. Infrastructure and boundaries themes yielded the next highest return in datasets (11 and 7 respectively), mostly of the former with government and the latter in academic institutions, respectively. The full overview of the datasets is available in the main report (COWI Tanzania, 2015).

Most respondents expressed a genuine interest in improving coastal data quality and access and all were willing to participating in an EIN initiative. Many agencies have been/are actively involved in generating and administering spatial data in Tanzania. The key player in the marine and coastal context is the Institute of Marine Sciences (IMS) at the University of Dar es Salaam. Other agencies that house smaller volumes of spatial and non-spatial data are Marine Parks and Reserves Unit, Sea Sense, Forestry Division, TAFIRI and ECO2.

There is little coordination and standardization of data sharing (hence the need for a national SDI). All agencies indicated willingness to participate in an EIN, but sharing of data will in most cases this will require a high-level agreement to formalize access to the datasets.

There is a considerable body of data for which details were not shared with the study. Data quality is assumed to be the main reason for the non-participation of those data stakeholders.

The Tanzanian Meteorological Agency has a client services unit and a full policy for data access; others indicated that they aim to develop client services units, understanding the need not to make access difficult (most departments still require a formal application via the Director or other executive).

Metadata does not exist for most datasets, and remains incomplete for IMS. Further, staff in many agencies was not aware of metadata management and creation, hence there is a strong need to update or create the good data infrastructure.

CONCLUSION

Coastal environmental data in Tanzania lacks the necessary quality, width and depth to represent a comprehensive basis for environmental assessments. In most cases, the proponents will have to gather data strictly for the purpose of their projects, not being able to draw on data approved and qualified by the government. There are currently no centralized overview of available data except for the one presented in this study.

A general lack of coastal environmental data will have consequences for effective management of marine and terrestrial wildlife. Lack of knowledge will also have negative impacts on land use planning, monitoring of oil and gas development in the country and other relevant decision making processes.

On the bright side, this short study of coastal and marine data in Tanzania has found that there is an excellent foundation for national spatial data in Tanzania, through an Environmental Information Network. The concept of data sharing and management under an EIN has wide support, but arrangements would need to be established to achieve the most user-friendly and accessible format for data sharing for such a network.

Based on the findings the report concludes that:

- the dataset overview should be continuously revised and updated through a continuing dialogue. The IMS meta-database may be the best foundation for NEMC to build upon.
- one should identify common gaps in datasets among the various institutions, the underlying reasons for these gaps, and establish an action plan for addressing them;
- one should identify institutions that are regularly collecting data and could benefit from support to improve data quality and coverage and data management (e.g. Fisheries Department, TAFIRI); practical support could be in the form of extension services, training or equipment;
- establish tactics to streamline standards in the harmonization of data to ensure reliability and accuracy of data (standards should address the question of frequency of updating data);
- update the TANSEA dataset project (in conjunction with the Coastal and Marine Atlas) and establish a means whereby that facility is maintained, hosted and of open access as originally foreseen;

- standards for metadata may need to be simplified but conforming to ISO 19115 2003. Stakeholders will need to be trained on how to write metadata for their datasets, but first the metadata version to be used will need to be promoted;

Oil and gas developments, direct or indirect, represent anthropogenic demands, which can have lasting consequences on land use at a local, regional, national and global level. Good management of environmental data can lead to a better knowledge basis, which again can lead to better decisions where wildlife and other environmental assets can have better conditions for long term conservation.

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DRIVERS OF TREE COMMUNITY COMPOSITION AND DEMOGRAPHY OF ACACIA ROBUSTA AND ACACIA TORTILIS SEEDS IN SERENGETI NATIONAL PARK

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ABSTRACT

Savannas are spatially diverse and susceptible to high rates of disturbance from fire and herbivory. While most studies in savanna have focused on tree/grass ratios and factors driving the dichotomy, less has been done to determine what drives species composition across environmental gradient and the role of seed stage in shaping the savannas. It is not clear how limitations such as production, infestation, viability, germination and dispersal are influenced by rainfall and what role they play in species composition turnover. Assessment on species compositional change across multiple environmental gradients in Serengeti National Park was done and the influence of long term rainfall gradient on seed limitations was tested. Quantification of the seed bottlenecks for two dominant tree species, Acacia tortilis and Acacia robusta and the analysis for their relationship with long term rainfall was done. Results showed that tree community composition is largely driven by mean annual precipitation and elephant population density. We also found that Acacia tortilis dominates the dry end of the ecosystem while Acacia robusta dominates the wet end. Fire showed no significant effect on species composition. Seed survival bottlenecks differed between species within years with no consistent patterns. Infestation did not completely inhibit germination. These results provide only weak support for rainfall-mediated effects on seed limitation for observed species turnover across the Serengeti rainfall gradient in adult trees, suggesting that post-germination filters may be more important.

Key words: *Acacia*, bottom-up factors, savanna, Serengeti, species composition, structural equation modeling, top-down effects.

INTRODUCTION

Savannas consist of co-occurring trees and grasses that are highly diverse and variable across space (Scholes and Walker, 1993). Extensive research on savanna vegetation has mostly focused on woody density vs. grass cover ratio plus factors controlling their co-existence (Bond, 2008, Sankaran et al., 2005). There has also been a significant interest on tree population dynamics in relation to disturbance regimes such as fire and herbivory (Baxter and Getz, 2008, Wakeling et al., 2011). These studies not only focus exclusively on seedlings and adult trees (Sankaran et al., 2004, February et al., 2013), but also less emphasis has been placed on understanding species composition and the role of seed stage in tree recruitment.

An ongoing debate in the savanna literature concerns the relative importance of bottom-up drivers (water and nutrients) vs. top-down factors (fire and herbivory) for vegetation structure, (Sankaran et al., 2004, Lehmann et al., 2009); but of equal interest is to understand how these two groups of variables influence tree community composition.

Tree recruitment process, is susceptible to demographic bottlenecks (Nathan and Muller-Landau, 2000). While some of the mechanisms determining seed production and viability in savannas are quite well studied (Walters and Milton, 2003), the role of rainfall and other processes influencing seed demography are less understood. For instance, in many African *Acacias*, seed germination is greatly impacted by bruchid beetle (*Bruchidius spadiceu*) infestation, with infestation rates as high as 80% reported in some studies (Okello and Young, 2000). However, the extent to which infestation is related to moisture or other environmental gradients, or whether it influences species turnover, remains unclear.

The aim of our study was to identify the environmental variables associated with variation in tree species composition. Also we aimed at quantifying seed demographic stages tree for tree species and their relationship with long term rainfall gradient.

MATERIALS AND METHODS

Study System

The study was conducted in The Serengeti National Park (Serengeti, hereafter, fig. 1), located in northern Tanzania. Serengeti (14,760 km^2) lies within a broader ecosystem extending over ~30,000 km^2, between 1350 and 1800 m asl.

Two main environmental features of the ecosystem are contrasting gradients of mean annual precipitation (which varies between ~ 600 and 1000 mm/y, increasing from SE to NW, fig. 1) and soil fertility (Sinclair, 1979, Holdo et al., 2009b). About two thirds of Serengeti can be described as true savanna, with the rest being an edaphic grassland on shallow volcanic soils. This study took place in the former, at sites conducive for tree establishment. The dominant tree species include *Acacia tortilis* and *A. robusta*. Sub-dominant species include *A. drepanolobium*, *A. senegal*, *Commiphora trothae* and *Balanites aegyptica*. The system is subjected to frequent fire and a diverse herbivore community dominated by grazers such as wildebeest (*Connochaetes taurinus*) and zebra (*Equus burcheli*), as well as browsers such as elephant (*Loxodonta africana*) and giraffe (*Giraffa camelopardalis*).

Data collection

A system of 38 plots clustered within 10 randomly selected sites spanning the Serengeti mean annual precipitation (MAP) gradient was used. The plots were 20 x 50 m (0.1-ha) in size and were initially established in 2009 (Anderson et al., 2015). Half of the plots are protected from fire, while the remaining half subjected to annual burn treatments. Within every plot, each individual woody stem > 0.5 m in height was identified to species and measured for basal diameter (BD) and diameter at breast height (DBH) annually. Two soil samples were collected at opposing corners (along the long axis) of each plot to a depth of 20 cm with a soil auger. Soil samples were weighed after drying in an oven at 65°C for at least 48 hours at the Serengeti Wildlife Research Centre and bulk density (BD) for each sample was calculated.

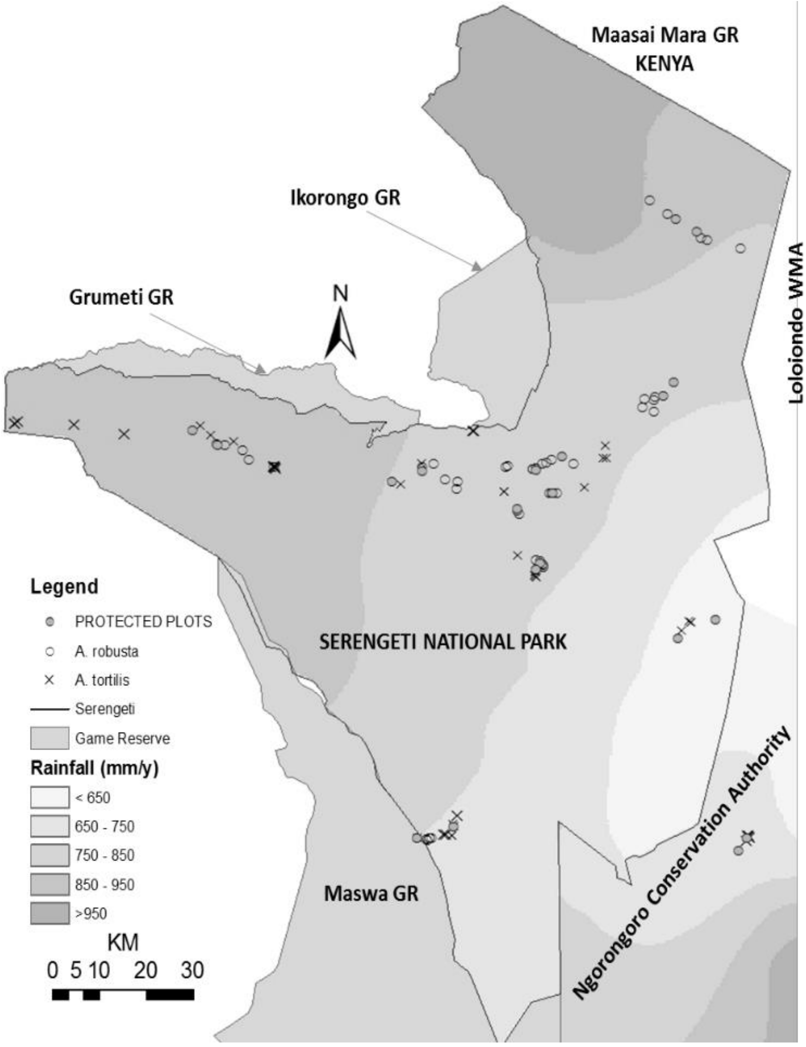

Figure 1: *Map of Serengeti and part of Ngorongoro showing plots, A. robusta and A. tortilis trees locations. The map also shows Mean Annual Precipitation isohyets and identifies game reserves buffering the park.*

Tree phenology (flowering and pod production) was quantified by visiting plots and collecting data on every individual tree > 2 m in height. On each visit, trees were scored as having pods or not for at least once a month between January 2013 and July 2014 (19 months). *Acacia tortilis* and *Acacia robusta* across sites were quantified for infestation proportion and germination potential. Seeds from sets of five fruiting mature trees per species per site were collected during two separate periods between February 2013 and August 2014. As seed production seemed to be patchy, and the timing of pod production varying across the system (Mduma et al., 2007), fruiting trees located beyond the plot boundaries were used. Seeds were sorted into infested (if had entry or exit holes made by bruchid beetles on their seed coat) and non-infested pools to obtain an infestation proportion per tree.

Primary seed dispersal was quantified using seed traps which were deployed inside the fire-protected plots. 10 seed traps (made with 5-gallon buckets arranged in two parallel lines spaced at 5-m intervals along the 50-m axis of the plot) were buried within each of the 20 x 50 m plots. A total of 160 traps were deployed at all sites except for NCA (logistic difficulties). To protect the falling seeds from possible predation and seed removal, the traps were covered with a thick wire mesh. The traps were checked at least once a month, and during each visit all seeds and pods were identified, counted, and removed. The ratio of trap area to plot area were used to estimate seed rain in seeds $plot^{-1}$ y^{-1} for each of the two species.

To study germination potential variation across sites, laboratory germination trials were conducted. Seed germination trays were used to plant both infested and non-infested seeds. The objective was to quantify germination potential as a function of species, infestation status and site long term rainfall (MAP). For each species, a known number (usually 100, fewer if sample sizes were insufficient) of infested and non-infested seeds were randomly selected for each site. The non-infested seeds were scarified slightly by cutting the seed-coat using a razor blade or gently scratching on sand paper to enhance overall germination. Infested seeds were not scarified as the bruchid exit holes allow water uptake by the seed (Lamprey et al., 1974). Seeds were planted into plastic germination trays filled with soil-soil mixture from around Serengeti research center. Each seed was covered with soil about one seed length deep and watered daily. The experiment was monitored every day for 35 days, and seed emergence date and number were recorded.

DATA ANALYSIS

Tree Community Composition

To characterize tree community composition across plots, a Non-Metric Multidimensional Scaling (NMDS) analysis was done on species-specific basal area (m^2ha^{-1}) per plot for all species with a basal diameter > 2 cm. Basal area values were converted to percent of total woody cover, then a *metaMDS* function in the R package *vegan* (Oksanen et al., 2013) was used for the analysis. Rare species in the analysis were excluded to just include only species that were present in three or more of the 38 plots (N = 10 species). Two-axis and three-axis models were tested and assessed for overall fit with the stress statistic. The plot scores on the NMDS axes were used as dependent variables in our subsequent analysis. Soils were analyzed to obtain total N, total C, and soil texture (clay, silt and sand fractions). By using the *prcomp* function in R, a principal component analysis (PCA) was conducted on the correlation matrix of four variables: BD, clay fraction (CLAY), total N (N) and C:N ratio (CN). The results these two components were retained for subsequent analysis.

Environmental variables

A number of GIS layers were used to extract additional environmental covariates for the plots using ArcMap 10.2.1 (ESRI, 2013). A digital elevation model (DEM), river layer, mean annual precipitation (MAP) layer and MODIS data from our GIS database for Serengeti were used to produce a slope layer at 90-m resolution, calculate distance (DIST) to major rivers, MAP and fire frequency (FIRE) for each plot respectively. Finally, 2008 aerial census data provided by Frankfurt Zoological Society were used to generate a map of elephant population density for the park. Elephant counts were used to calculate elephant population densities (variable ELE) within circular neighborhoods with 10 km radius centered on each plot.

A set of 13 *a priori* candidate models relating community composition based on the NMDS analysis were developed for different combinations of plot-level environmental main covariates. Linear mixed models implemented with the *lme* function in the *nlme* package (Pinheiro and Bates, 2000) in R were used in which environmental variables were treated as fixed effects and SITE as a random effect. Model fits were compared with the Akaike Information Criterion corrected for small sample size (AIC_C) independently for MDS1 and MDS2.

Seed demographic bottlenecks

Most of the analyses included regressions, testing seed limitation variable responses to MAP. Data from all seed experiments were pooled to a site level in which proportion of seed production, infestation rate and viability were computed. The general approach to the analysis was the use of generalized linear mixed models (GLMMs) using the *glmer* function from the R package (Bates et al., 2007). In several analyses, year of collection was included as a covariate and treated as fixed effect.

For the phenology analysis, we first computed site-level proportions of pod production and plotted production as a function of MAP. We developed a set of five candidate models containing combinations of tree height, basal area and species as fixed effects, and used the *glmer* function with a binomial distribution to fit the models. For the infestation analysis, we used a set of seven candidate models, including an intercept (null) model plus six others -

combining effects of MAP, species and year (plus some interactions of interest). The model selection exercise was conducted with the *lme* function in the *nlme* package in R (Pinheiro et al. 2011) using SITE as a random effect.

For the laboratory seed germination trials, the cumulative numbers of germinated (N_c) and ungerminated ($N_{initial}$ - N_c) seeds at the end of the 35-day trial period were used as the response variables in a binomial distribution. Seven candidate models that included an intercept model plus six explanatory models that included main effects of MAP, species and/or infestation status plus some targeted interaction effects, were fitted using *glmer* with a binomial error. In the seed rain study, seeds were consolidated by plot and species, and used to estimate mean annual seed rain at the plot level. The site-level means of this metric are reported.

RESULTS

Tree Community Composition

The NMDS analysis generated a satisfactory stress value (0.09) with two axes, so the analysis was restricted to a two-dimensional model. A visual examination of environmental variable associations with the NMDS axes suggested positive relationship between MDS1 and MAP and elephant population density (ELE). The two dominant tree species in the community separated clearly along these axes: *Acacia tortilis* being associated with dry, fertile sites, while *A. robusta* with wetter environments (Fig. 2(a)).

Model selection exercise supported clear association between the first community axis (MDS1) and MAP and ELE while other covariates, including fire frequency (FIRE) and soil variables did not improved model fit (Table 1). The results suggest that the primary drivers of variation in tree community composition across Serengeti are soil moisture (as related to mean annual rainfall), and possibly elephant herbivory.

Seed demographic bottlenecks

Over the two-year period of the study, 585 individual trees (260 of the two focal species) were visited between 5 and 10 times for the determination of pod production. There was clearly no relationship between pod production proportion and MAP for either species (Fig. 3).

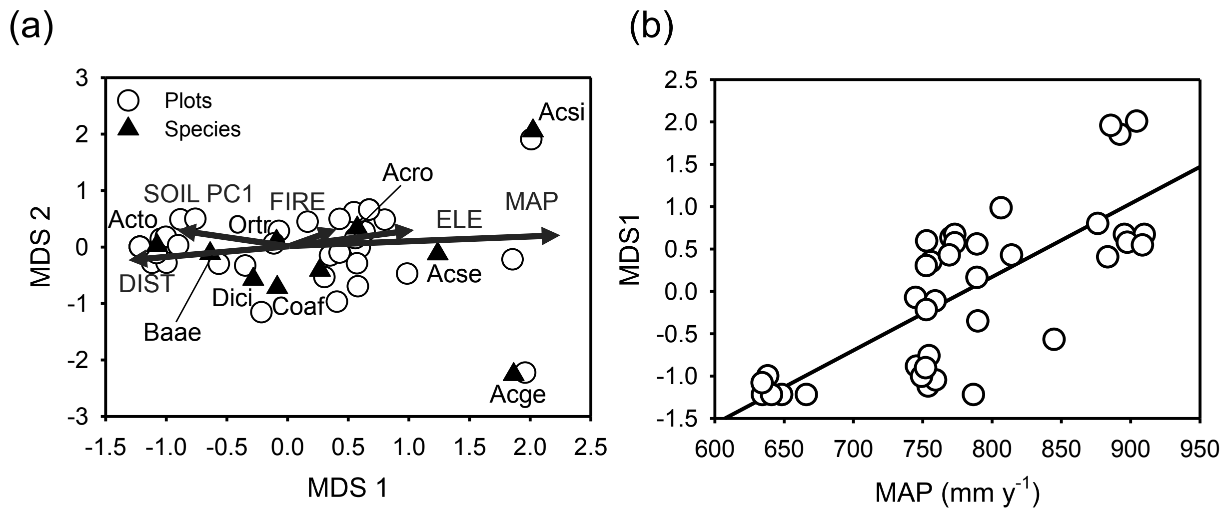

Figure 2: *(A) Plot and species scores on axes 1 and 2 of the tree community NMDS analysis, with a subset of environmental variables shown as vectors (correlations with NMDS axes across plots). Labels identify species (Key: Acge = Acacia gerrardi, Acro = A. robusta, Acsi = A. sieberiana, Acse = A. senegal, Acto = A. tortilis, Baae = Balanites aegyptica, Coaf = Commiphora africana, Dici = Dichrostachys cinerea, Ortr = Ormocarpum trothae). (b) Tree community axis 1 (MDS1) as a function of mean annual precipitation (MAP) across 38 Serengeti NP vegetation plots.*

Table 1: Model fits (AICc, the Akaike Information criterion corrected for small sample sizes) for tree community structure (axis 1 of an NMDS analysis) to alternative combinations of environmental covariates.

Model†	**df**	**AICc**	**ΔAICc**
INTERCEPT	3	95.9	19.0
MAP	4	79.4	2.4
MAP + SLOPE	5	81.8	4.9
MAP + SOIL PC1	5	80.6	3.6
MAP + FIRE	5	80.3	3.3
MAP + ELE	**5**	**77.0**	**0.0**
MAP + ELE + SOIL PC1	6	79.3	2.3
MAP + ELE + SOIL PC1 + SOIL PC2	7	79.1	2.1
SLOPE + MAP + FIRE	6	82.5	5.6
SLOPE × MAP	6	84.7	7.7
MAP + DIST + ELE	6	78.3	1.3

MAP + DIST + ELE + SOIL PC1	7	81.3	4.3
MAP + DIST	5	81.3	4.4
MAP + DIST + FIRE + ELE	7	80.8	3.8

†*See text for variable descriptions; in all cases SITE was treated as a random effect*

Model selection results showed that a model containing species and height effects provided the best fit to the data. The species effect alone did not improve model fit over a null model (ΔAIC < 2), but the addition of height (a positive effect) improved fit over the species-only model (ΔAIC = 5.4).

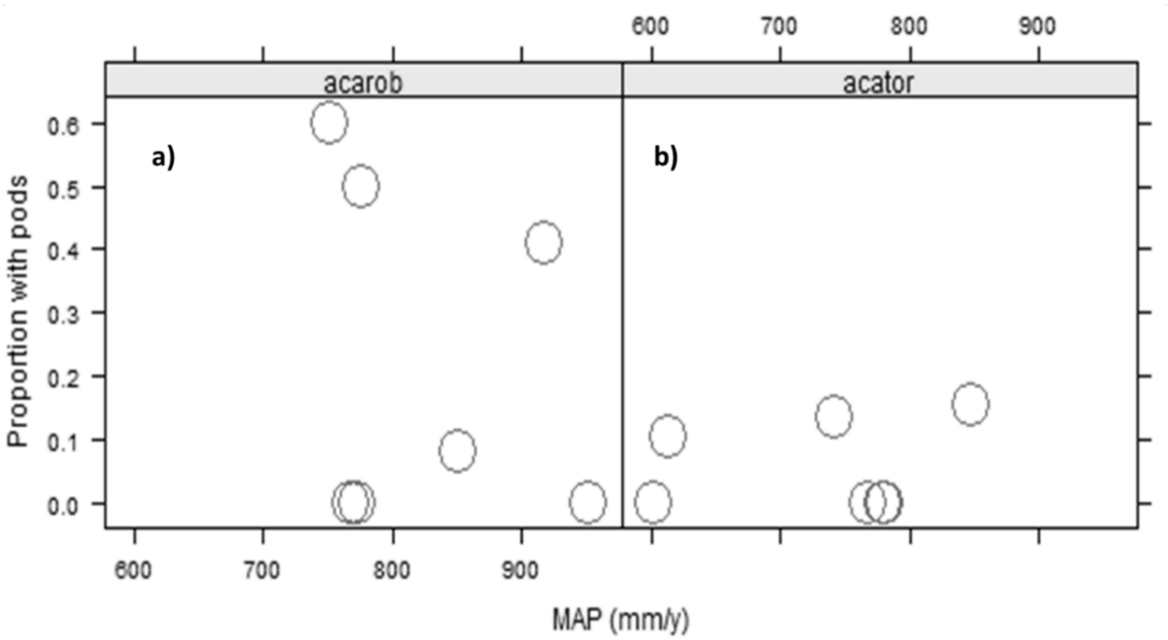

Figure 3. *Pod production in a) A. robusta (acarob) and b) A. tortilis (acator) as a function of MAP.*

Bivariate scatterplots suggested that infestation rates differed between species within years, with *A. tortilis* seeds showing high infestation rates in 2013 relative to *A. robusta*, but with the pattern reversing in 2014 (Fig 4). Model selection results suggested that only species and collection year (and their interaction) explained differences in infestation among sites. The model with species effects only did not improve over the intercept model (Table 2), but the species x year model did, suggesting that variation in infestation among species is not consistent. MAP did not improve model fit either alone or in combination with any of the other covariates (Table 2).

Under laboratory conditions, as expected non-infested seed for both species showed higher germination compared to infested seeds. *A. tortilis* seeds had a maximum germination proportion of about 70% while *A. robusta* seldom exceeded 25%, suggesting that, *A. tortilis* has a higher germination potential than *A. robusta*.

Against expectations, infestation did not completely inhibit germination. The model selection exercise revealed two things; first, the rate of germination was affected mainly by the interaction between infestation rate and species differences for 2013, and second, germination rates in *A. robusta* were positively related to MAP at collection site (fig 2.6).

In 2013, model selection results suggested that only species and infestation status explained differences in germination among sites. The model with species effects only did not improve over the intercept model (Table 2.2), but the interaction (species × infestation status) model did, suggesting that variation in germination among species is not determined by species.

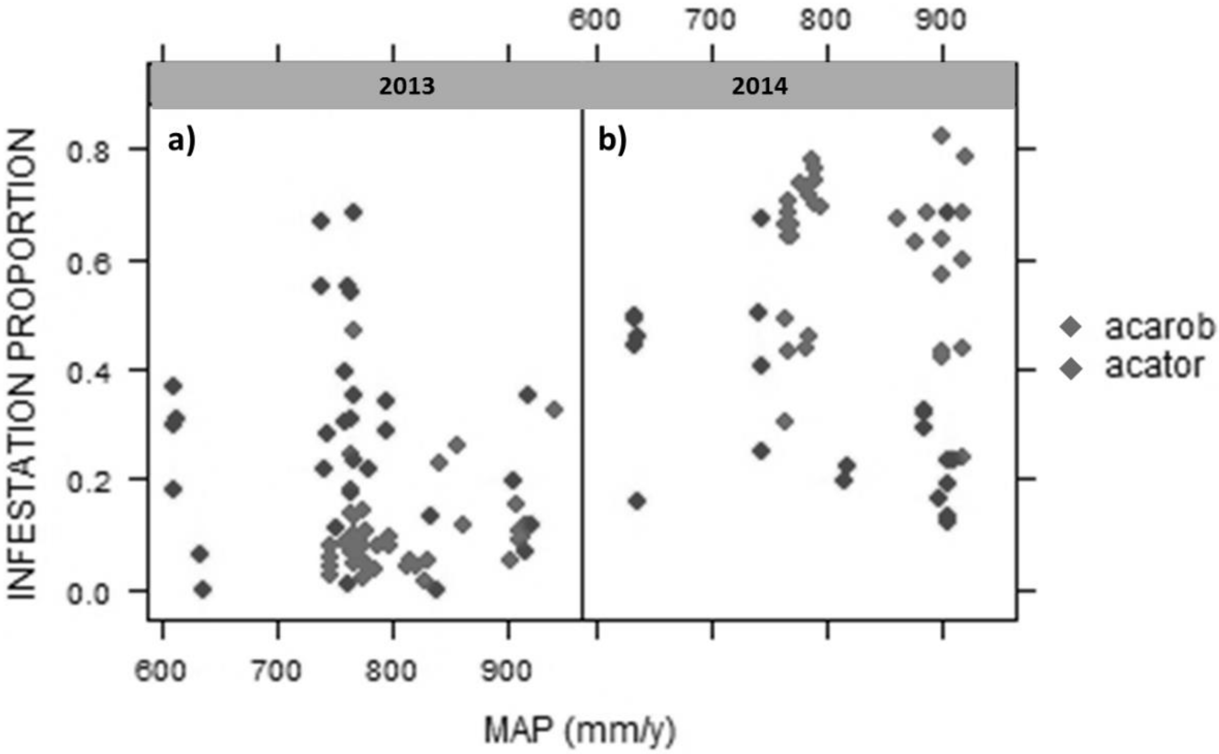

Figure 4: *Infestation proportions for A. robusta and A. tortilis and A. robusta in **a)** 2013 and **b)** 2014.*

Table 2. Model fits (AIC, the Akaike Information criterion) for the effect of MAP, species, year and their interaction on infestation proportion using generalized linear mixed-effects models

Model fixed effects	df	AIC	ΔAIC
INTERCEPT	3	435	95
MAP	4	448	108
MAP + SPECIES	5	451	111
MAP + SPECIES + YEAR	6	382	42
MAP × SPECIES	6	459	119
SPECIES × YEAR	**6**	**340**	**0.0**
MAP + SPECIES + YEAR + MAP × SPECIES + YEAR × SPECIES	8	362	23

MAP did not improve model fit either alone or in combination with any of the other covariates (Table 2), suggesting that long term site condition is not a factor for germination difference. In 2014, model selection results suggest that the interaction between MAP, species and infestation status explain the difference in germination rates. Again, the model containing species or MAP only did not improve over intercept model, suggesting that these covariates are independently explaining differences in germination rates.

Table 3. Model fits (AIC, the Akaike Information criterion) for the effect of MAP, species, infestation and their interaction on germination rates using generalized linear mixed-effects models

FIXED EFFECTS MODEL	2013			2014		
	df	AIC	Δ AIC	df	AIC	Δ AIC
INTERSEPT	2	1012	771	2	509	393
MAP	3	1012	771	3	511	394
SPECIES	3	733	493	3	477	360
SPECIES + INFESTED	4	290	50	4	143	26
MAP.resc + SPECIES + INFESTED	5	292	52	5	143	27
MAP * SPECIES + INFESTED	6	290	50	6	**117**	**0**
SPECIES * INFESTED	5	**240**	**0**	5	140	24

The scatter plots results for the germination proportion as a function of rainfall for both species (*fig. not included*) showed that in both years infested seeds had lower germination rates compared to non-infested rates. Also germination rates showed no relationship with long term rainfall except for 2014 where *A. robusta* was positively related with MAP at collection sites, suggesting inconsistent pattern between years.

Over the course of the study, seed rain was low yielding a total of 137 seeds collected from the 180 seed traps, with *A. robusta* and *A. tortilis* seeds being present in 4 and 3 of the 18 plots, respectively. There was no relationship between seed rain and MAP for either species.

DISCUSSION AND CONCLUSION

Our results suggest that tree community composition in Serengeti is largely driven by resource availability (as represented by rainfall), and to a lesser extent by elephant herbivory. Although fire has been shown to regulate tree size classes and density in the Serengeti over the past few decades (Pellew, 1983, Dublin, 1995, Holdo et al., 2009a), these results suggest that it plays a negligible role in regulating tree species composition. Given the long history of fire in Serengeti (Sinclair et al., 2007) and its effect on tree density, one interpretation for the lack of a fire signal in our study may be that fire-susceptible species may have largely been filtered out of the savanna portions of this system. They are also probably currently confined to riverine forests and those that remain exhibit similar tolerances to this form of disturbance.

Prolonged herbivory has also long been an evolutionary force in African savannas, and some tree species are uniquely adapted to withstand browsing (Staver et al., 2012). In conjunction with strong selective feeding by elephants in this system (Morrison et al., *In Press*), this can lead to changes in tree community composition over time, particularly in the larger size classes favored by elephants as source of food.

Our models suggested that the proportion of trees producing seeds increased with tree height, but did not differ between species. Also we found no significant relationship between proportion of trees producing seeds and MAP in both species. This suggests that, seed production can be explained by species morphological traits rather than environmental variables. These results differ from other previous hypothesis suggesting that increase in moisture leads to successful seed production and growth of seedlings (Greene and Johnson, 1994). It has been previously suggested that plant growth is water limited in savannas, so greater soil moisture availability may lead to higher production of seeds (Salazar et al., 2011). While this study did not focus on the suitability of the microsites where these seeds land, long term MAP was our main covariate for inference and we think this scenario may respond differently if analysis involved rainfall values for years that data were collected. Analysis is underway to tease this apart.

Germination rates under laboratory conditions were higher in *A. tortilis* than in *A. robusta* and strongly reduced by insect infestation, although infestation did not completely inhibit germination. While these findings on the contrary contradict with a study on *A. tortilis* which reported absence of germination of infested seeds (Ahmed, 2008), they correspond to a study by (Mucunguzi, 1995) on germination of infested seeds who reported that beetles reduced the germination but promoted early germination. Our hypothesis for these contradicting results is that seed mass and intensity of predation may play a role where larger seeds have more cotyledons compared to smaller seeds (Leishman, 2001). This may lead to some seeds managing to have larger quantity of food reserve than the beetles can exhaust and hence increasing the chances of germination.

Seed rain study revealed patchy low amount of seed collected in traps. These findings are relatively similar to the findings by (Salazar et al., 2011) although with relatively different seed density. Salazar et.al, (2011) estimated seed rain for Neotropical savanna trees for 23 species where they collected more seeds per unit area (ca.19 seeds m^{-2}) than what we report here (ca. 0.14 seeds m^{-2} or 20 seeds per plot). We find it difficult to pinpoint with certainty the reason for low seed rain but we think many factors may contribute to this such as pollination limitation (Brown et al., 2003).

Our results also suggest that infestation rates differed between species within years, but *A. tortilis* seeds were highly infested in the first year of study relative to *A. robusta*, but with the trend reversing in the subsequent year. This inconsistent trend suggests that species type and collection year explain differences in infestation among sites. Seed infestation has been reported in several ecosystems as a factor for reduced tree recruitment (Rohner and Ward, 1999). In this study we predicted higher infestation in mesic sites than dry sites assuming favorable conditions for pests in those sites. The findings did not support the suggestion that infestation is not explained by long term

MAP.

In conclusion, our findings show that woody species composition varies across the key Serengeti environmental gradient and that rainfall and elephant density are the most likely drivers of this variation. Our study revealed species variation in stages of seed limitation and no clear effect of long term MAP suggesting that tree community patterns are not generated at the seed stage. Also our study suggest that seed limitation is likely important and probably depends on current rainfall regime rather than long term rainfall. We think the results of this experiment are helpful in understanding the role of moisture and larger herbivores in influencing species composition. Also, these results shade light by providing useful information for restoration ecology as they show how different bottlenecks in savanna affect tree recruitment.

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IMPORTANCE OF ETHNO-MEDICINAL PLANTS AMONGST THE IRAQW OF KARATU DISTRICT, TANZANIA: CULTURAL AND CONSERVATION IMPLICATIONS

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ABSTRACT
Medicinal plants are valuable in their provision of products that are used by communities in treating various ailments. However, most of the valuable medicinal plants are facing threat of local extinction in the areas they have traditionally occurred, and in most landscapes the conservation status, the traditional knowledge of their utilization is often not understood. In this study, we document the conservation status, utilization by indigenous communities and threats to 32 species of medical plants in Buger village, Karatu District in Tanzania using semi-structured interviews. Only 30.2% of indigenous community members indicated that they use ethno-medicinal plants to treat human diseases. The most common diseases treated by these medicinal plants were stomach diseases, common colds, menstruation, malaria and dental pains. Most of these medicinal plants were collected from small farms around the households. Matrix analysis showed that Mgunga moto (Acacia mellifera), Msokoni (Warburgia salutaris), and Durang (Faurea speciosa) were the top ranked most important species used for medicine followed by Matsafi (Fagaropsis angolensis) and Garmo (Acacia albida). Results also showed that the use of ethno-medicinal plants is dependent upon education level but not on gender and age class structures. Young people lacked a detailed understanding of the value and importance of ethno-medicinal plants, Community members noted that the availability of these plants was decreasing in the area. Therefore, awareness on young people on their values and knowledge on use will improve medicinal plants values and wide use among the communities in the area. It should be emphasized that controlled harvesting of these plants and conservation of the Buger Community forest will improve their sustainable availabilities.

Key words: Endabash, Iraqw people, Plant utilization, human disease, medicinal plants.

INTRODUCTION

The World Health Organization (WHO) estimates that roughly 80% of the African population is still using traditional medicine to bolster healthcare (WHO, 2002). In Kenya, for example, ethno-medicine constitutes 75 to 90% of local community healthcare (Ochieng' Obado & Odera, 1995; Sindiga *et al.*, 1995a, b). Tanzania is no exception. Despite the advent of western medicine, it's estimated that as many as 80% of rural Tanzanians of varying ethnic descent are still relying on ethno-medicinal plants as their primary form of health care to treat not only disease and illness, but for hygiene as well (Fraktin, 1996; Sindiga, 1995a-e; Kitula, 2007). A study conducted in the Hai Mashariki division along the southern slope of Mt. Kilimanjaro in Tanzania found that 30% of all trees in Chagga home gardens produce medicine for either humans or animals (O'Ktingati, 1986; Hines & Eckman, 1993). Other research in the Iringa region, at the New Dabaga Ulongambi Forest Reserve, revealed 45 different plant species responsible for curing 22 human diseases (Kitula, 2007).

The kinds of ailments treated by ethno-medicinal plants range from serious to minor. They include a number of gastro-intestinal, bacterial, viral, neurological or reproductive issues, ranging from the common cold and diarrhea, to bilharzia, epilepsy and malaria. Based on semi-structured questionnaires conducted in Kikuku village, Muleba District, 49 plant species belonging to 47 genera and 24 plant families were used by locals to treat bacterial infections, skin conditions, malaria, gastrointestinal disorders, gynecological problems, hypertension, viral infections, diabetes, cancer, HIV and AIDS, arthritis and hernias (Moshi *et al.* 2012). One study found the number of plant species exploited for bodily and dental hygiene among the Maasai of Sekenani Valley to be 15 out of 39 total species (Bussman *et. al.* 2006). In New Dabaga Ulongambi Forest Reserve, roots were the most commonly harvested part of the plant at 44.3%, followed by leaves, 23.6%, and fruits, 11.8% (Kitula, 2007).

Ethno-medicinal plant use is influenced by several political and social factors. An inadequate number of local clinics and hospital personnel, with an average doctor to patient ratio of 1:540 is one reason why it still remains popular in the Iringa region (Kitula, 2007). Other factors contributing to their continued usage are average household income (roughly 250, 434. 78 Tsh) and traditional beliefs (Kitula, 2007). Despite the positive effect these factors have on ethno-medicinal plant use, traditional systems of medicine in East Africa are rapidly disappearing under the pressure of western influence. Even among the Maasai, an east African ethnic group notorious for retaining traditional elements of their culture, the generational transmission of medicinal plant knowledge is being threatened by lifestyle changes associated with modernization (Kiringe, 2006). Where Maasai were once reported to exploit as many as 500 plant species, a recent study in Sekenani Valley, Maasai Mara, Kenya, revealed just 104 (Bussman *et. al.* 2006; Kiringe, 2006). The decline in botanical cures over the last century may be attributed in part to the "Witchcraft Act" of 1925, which outlawed traditional medicine in Kenya (Busman *et al.*, 2006). However, more recent drivers are the increasing popularity of Christianity and modern education (Kiringe, 2006; Bussman *et al.*2006).

Habitat loss and disconnection in traditional knowledge on these medicinal plants are the factors endangering medicinal plant species survival. According to the International Union for Conservation of Nature (IUCN), primary threats to medicinal plant resources in developing countries such as Tanzania includes unmonitored trade of medicinal plant resources, destructive harvesting techniques, overexploitation and habitat loss (IUCN, 2001 & 2002). Most of the plants used in traditional medicine are collected from wild plants. Therefore, there is concern for genetic erosion, which calls for conservation plans to ensure long-lasting uses of ethno-medicine. For rarer plant species, the IUCN recommends cultivation as an alternative to collecting wild plant species (IUCN, 2001). Various sets of recommendations have been compiled relating to conservation of medicinal plants: the need for coordinated conservation actions based on both *in situ* and *ex situ* strategies, inclusion of community and gender perspectives in the development of policies and programmes, the establishment of systems for inventorying and monitoring the status of medicinal plants, the development of sustainable harvesting practices, encouragement for microenterprise development by indigenous and rural communities, and the protection of traditional resource and intellectual property rights (Akerele *et al*. 1991; Bodeker, 2002).

While information stressing the importance of ethno-medicinal plant use exists among well-documented ethnic groups such as the Maasai, it's relatively lacking in relation to the Iraqw. In general, recording the curative aspects of certain plant species involved in community health care is important if any of their pharmaceutical benefits hope to be fully realized. Beyond proving useful as household medicines, many local plants have untapped pharmaceutical properties that can be studied and utilized by the medical community. Moreover, the sell of medicinal plants is an industry that supports local livelihoods; vendors can earn up to TZS. 200,000 (Kitula, 2007). However, the multi-purposefulness of such endemic and common plant species that warrants further research is being threatened by rapid flora and fauna disappearance due to agriculture, population growth and human settlement. An assessment of available plant species will hopefully incentivize regional conservation projects, at the household and local administrative level. Moreover, because plants with medicinal properties are not only locally, but commercially exploitable, the national or district level government should explore funding programs that aim to educate members of the community on medicinal plants. The loss of medicinal plant knowledge threatens local health and livelihoods on a micro level, and medical innovation on a macro level.

This study was carried out between April to December 2014 to provide insights of the importance of ethno-medicinal plants among the Iraqw people of Endabash area in Karatu district, northern Tanzania and their status in the area. Specifically, the study objectives were:

- To assess the traditional knowledge among the community on the use of plants for medicinal purposes.
- To document the availability of plants used for ethno-medicines in the area.
- To document the usage of ethno-medicinal plants among the Iraqw of Buger village.
- To recommend appropriate conservation techniques to preserve the plant species for future use.

MATERIALS AND METHODS

Study area

This study was conducted in Buger, Ayalalilo and Kambi ya Faru villages of Karatu district in Arusha region, northern Tanzania. Geographical features of the Karatu district include the Rift Valley Escarpment, harboring both Lake Manyara and Lake Eyasi which impact the area's hydrology as well as climate (Mkomwa et al., 2011). Rainfall is bimodal and ranges from less than 400mm (semi-arid) to 1000mm (sub-humid) (Mkomwa *et al.*, 2011). The villages of focus were located just west of the Marang Forest Reserve (Figure 1). The forest area is hilly and characterized by a large plateau, elevation is 1600-2000m, vegetation ranges from dense upland forest to scrub/bushland to grassland (AWF, 2003). The predominant ethnic group in the area is Iraqw whose livelihood is based primarily on pastoralism and agriculture as well as resource extraction from the forest reserve (Yanda and Madulu, 2005). Agriculture ranges from subsistence to large-scale (commonly maize), pastoralism (mainly cattle and goats and sheep) is largely subsistence-based (AWF, 2003).

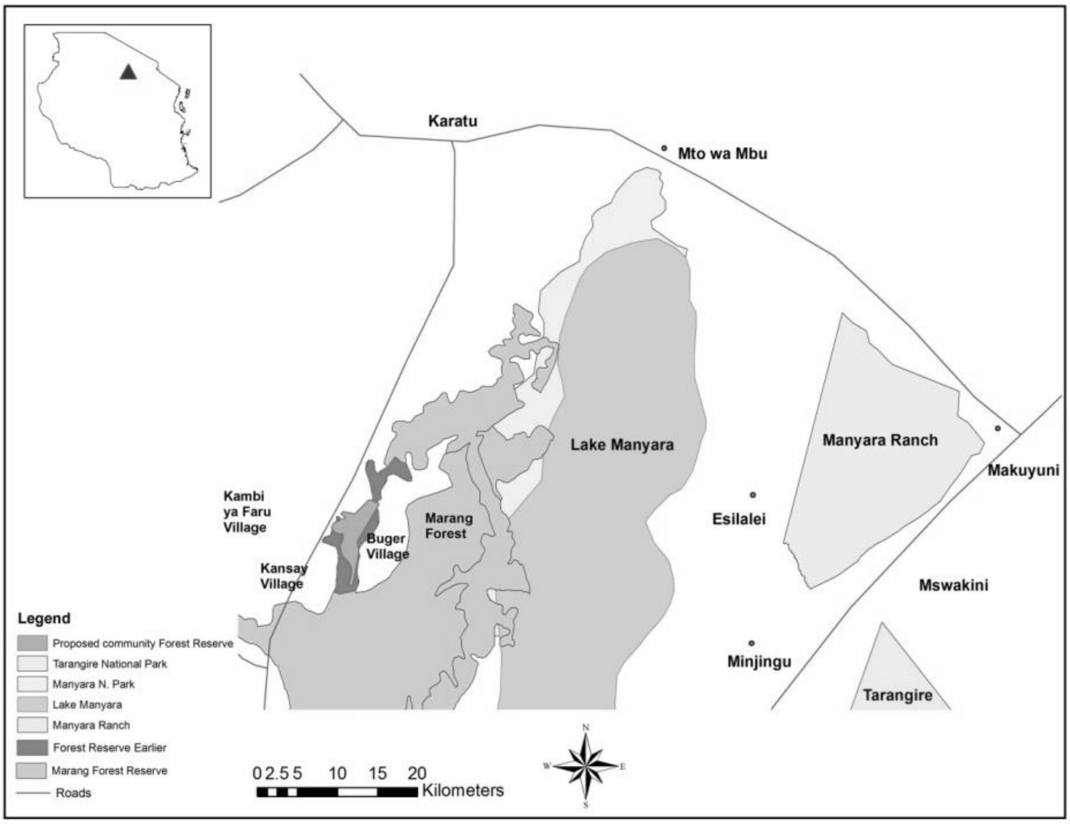

Figure 1: *Location of the study area in Karatu district which shows Buger, Kansay and Kambi ya Faru villages and their adjacent forests.*

Data Collection:

Semi-structured questionnaire was administered to the study area community members to collect information on utilization of tree and other plant resources for medicinal purposes. The main questions focused on the following aspects: commonly utilized tree and shrub species; parts utilized; common diseases treated; these plant resources availability trends; local people knowledge ethno-medicinal uses. The household for interview were randomly selected, and for each house with the help of local Iraqw interpreter and guide a questionnaire was administered to head of the household or any adult members (18 years old or above) present at that moment.

Data collected through questionnaire were analyzed by using Statistical Package for Social Science (SPSS) computer programme. Scientific identifications of the ethno-medicinal plants were done by the researcher (as he is knowledgeable in plants identification) with the help of plants identification books for confirmation.

To determine the availability of plants used for ethno-medicinal in the Buger community forest, data was systematically collected from a total of 88 concentric circular plots of 15 meter radius that were established 250 meters apart from each other along the 12 transects that were 500 meter parallel apart laid down by the use of Silva Compass. The plots sampled 4% area of about 781 hectors of the forest. Circular plots were chosen because they are most convenient to establish in the field because they minimize counting errors compared to square and rectangular plots (Giliba et al., 2011). Within the plots, the number of tree species, abundance and medicinal utilization of tree or plant species were recorded. Concentric circle radii were marked at each sample plot using a 20-meter tape measure. All trees within a 2-meter radius of plot points were recorded. Trees between a 2- and 5-meter radius were recorded only when the DBH measurement was greater than 5 centimeters. Trees between a 5- and 10-meter radius were recorded when the DBH was greater than 10 cm. Trees between 10- and 15-meter radius were recorded when the DBH was greater than 20 cm. The tree was then placed into a size category based on its diameter at breast height (>4.0 cm, 4.0-7.9 cm, 8.0-14.9cm, 15.0-29.9 cm, 30.0-49.9 cm, and >50.0 cm). The locations of the plots were recorded using a handheld Garmin two plus Global Positioning System (GPS). Two local Iraqw herbalists' guides helped with species identification and also as interpreters.

RESULTS

Ethno-medicine

In this study a total of 106 respondents were interviewed, and 31 medicinal plant species used for human diseases were documented. Amongst the 106 respondents, 69.8% indicated that they do not use ethno-medicinal plants while 30.2% indicated they do use ethno-medicine.

The ethno-medicinal uses of the 31 species documented through the interviews, focus group discussions, and data collected from the community forest are cited in Table 1.

Table 1: Commonly used medicinal plants to treat human diseases in the Buger region

Number	Iraqw Name	Scientific Name	Utilization	Part of Plant	Preparation
1	Aanqway	*Azadirachta indica*	Malaria	Bark and leaves	Boiling
2	Ankwi	*Vernonia exsertiflora*	Medicine for deep cuts	Leaves	Crush the leaves and squeeze the juice on wound
3	Meali	*Croton microstachys*	Joint pain	Bark and leaves	Boil in water and drink
4	Durang	*Faurea Speciosa*	PMS for women/ Malaria	roots	Boil in water and drink
5	Eucalyptus	*Eucalyptus globulus*	Menstruation / PMS	Bark	Boils in water and drinks it in hot water
6	Garmo	*Acacia albida*	Brush teeth/dental medicine	Bark	Chewing the barl of small branch
7	Qualalandi	*Ziziphus mucronata*	Birth control	leaves	Boil leaves in water and drink
8	Guava leaves	*Psidium guava*	Stomach pain	leaves	Boil leaves in water and drink
9	Haharamo	*Cordia sinensis*	Malaria, STD's	roots	Not revealed by herbalists
10	Hhangali	*Solanum incanum*	Stomach pain and worms	Fruit, leaves, bark, roots	Eat roots or drink fruit juice, or boil roots and drink
11	Baryomodi	*Acacia nilotica*	Digestion (stomach)	Roots	Boil roots in water and drink
12	Ayloi	Croton megalocarpus	Stomach pain (causes diarrhea to rid body of stomach parasites)	bark	Grind the bark, place one teaspoon into boiling water

Number	Iraqw Name	Scientific Name	Utilization	Part of Plant	Preparation
13	Maayangu	*Ximenia caffra*	Colds; Gonorrhea, ulcers in stomach, treats fresh cut wounds	Bark, roots, leaves	Grind bark into powder mixed with sandal wood and put in tea to drink; grind up roots, drink for ulcers in stomach and place boiled leaves on fresh cut wounds
14	Maslaramo	*Vangaena infausta*	Stomach medicine	Fruit, bark, leaves	Boil bark in water drink while hot.
15	Matsafi	*Fagaropsis angolensis*	Malaria, colds	Flowers for colds	Smells the flower to stop his cold
16	Maheli	*Myrisine africana*	Treat skin diseases	Latex liquid from tree	Place the liquid on the skin
17	Mgunga	*Acacia spp.*	Allergies	Bark	Boil bark in water and drink
18	Mgunga Moto	*Acacia mellyere*	Stomach illness	Bark	Boil in water and drink
19	Minighiti	*Euclea spp.*	Stomach pains	bark	Grind up bark and stirrer in water and drink
20	Mori	*Scolopia spp.*	Prostate treatment/ men's health	roots	Boil the roots in water and drink
21	SIrongi	*Rhus natalensis*	Pneumonia and cold	Bark	Grind bark into powder mixed with sandal wood and maayangu and put in tea to drink

Number	Iraqw Name	Scientific Name	Utilization	Part of Plant	Preparation
22	Msokoni	*Warburgia salutaris*	Colds	Leaves, roots	Grinds leaves and roots for tea
23	Nughay	*Hoslundia opposite*	Medicine for men to remove impotence	roots	Chew roots
24	Qarrengei	*Aloe* barbadensis	STD's, animal disease, stomach problems, fresh cut wounds, eye pain; stomach pains	Liquid, branches	Can drink, apply for wounded areas; branches for stomach pains
25	Sakwanay	*Warbugia ugandensis*	Stomach pains, general pain and to wash pubic areas, pneumonia	Bark	Grind bark and put in hot water of porridge or tea
26	Sandal wood	*Osyris lanceolata*	Pneumonia, Malaria, STD's, chest pain; colds	Roots, bark	Grind up bark and roots and put in porridge/drink like tea; Grind bark into powder mixed with sandal wood and maayangu and put in tea to drink
27	Slonsli	*Terminalia mollis*	Fractured bone pain	Leaves	Place leaves in hot water and place hot leaves on fracture
28	Tlaghmo	*Clerodendrum myricoides*	Stomach medicine	Bark	Dry bark and grind it then put in porridge

Number	Iraqw Name	Scientific Name	Utilization	Part of Plant	Preparation
29	Washawasha	*Senna alata*	STD's and kidney	Roots	Boil in water
30	Kwasxari	*Kigelia africana*	Cold, cough	Roots	Roots are eaten raw
31	Awakii	*Acacia xanthophloea*	Diarrhea	Bark	N/A

The plant parts used widely for the treatment of human diseases included bark, leaves, roots, flowers and fruits are listed in Table 2. The most commonly used plant parts for remedy preparation were the bark (37.5%) and leaves (29.0%).

Table 2. Medicinal plant parts used by the Iraqw people for remedy preparation

Plant part used	No. of Species	Percent of species
Bark	11	35.5%
Leaves	9	29.0%
Roots	8	25.8%
Flowers	1	3.2%
Fruit	2	6.4%
Total	**31 plant species**	**~100%**

From the interview data and focus group discussions it was apparent that medicinal plants have various methods of preparation and application for different types of ailments. They commonly form concoctions that have powdered bark, leaves, or roots that are homogenized in water to form a tea or mixed in porridge. The preparation and application methods vary based upon the type of disease treated and the actual site of the ailment. Different routes of application included oral, topical, or dermal routes.

Disease types in the Buger region

The interview data (Figure 2) indicated that Malaria was the most common disease (47%) followed by common cold (21%).

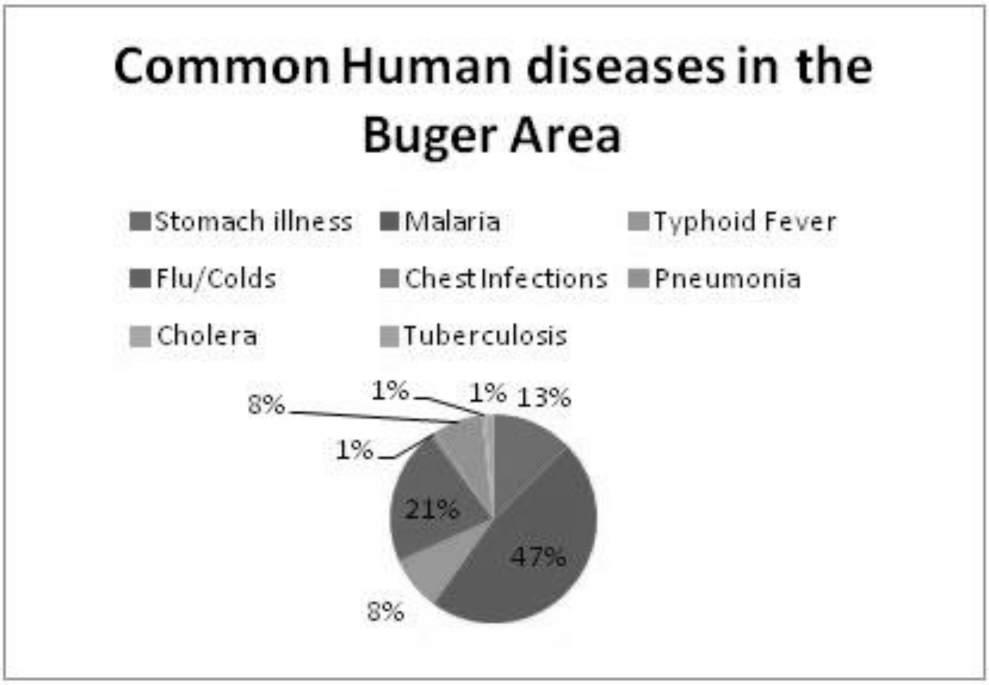

Figure 2: *Common human disease prevalent in the Buger region*

Preference direct matrix ranking of medicinal plants used to treat human diseases

According to the matrix ranking of preferred medicinal plants used to treat human diseases obtained during a focus group discussion, Mgunga moto (*Acacia mellyere)*, Msokoni, and Durang were the top ranked species used for medicine followed by Matsafi and Garmo. Mgunga moto is used to treat stomach diseases and Msokoni treats common colds. Durang is used to treat Period Menstruation Sickness symptoms as well as Malaria. Matsafi is used to treat both common colds and malaria. Lastly, Garmo is used to treat dental diseases, and the bark is often used as a "toothbrush."

Cultural and socio-economic implications with the use of ethno-medicinal plants

Aside from medicinal importance, many informants in the focus group discussions mentioned that plants used for medicinal purposes were also used for other reasons such as for food, honey collection, firewood, and construction materials. The matrix ranking showed that the tree Minighiti (*Euclea spp.)* was preferred for construction materials. Medicinally, the bark of Minighiti was used to treat stomach diseases. Similarly, Minighiti was also used for firewood and was highly preferred amongst the people in the Buger region. Maslaramo (*Vangaena madagascaneinsis),* which was used to treat stomach diseases, was also used for firewood and honey collection and eaten as fruit. Msokoni is often used to treat common colds; however it can also be used for honey collection.

Factors that affect use of ethno-medicinal plants

Several factors were tested in relation to use of ethno-medicinal plants including gender, education level, and age class structures. Out of 106 respondents, the percentage of males within the population using ethno-medicinal plants was 49.1% while the female percentage was 50.9%.

Amongst age class structures, the highest use of ethno-medicinal plants was for people between the age of 36 and 45 years old (29.2%, Figure 3).

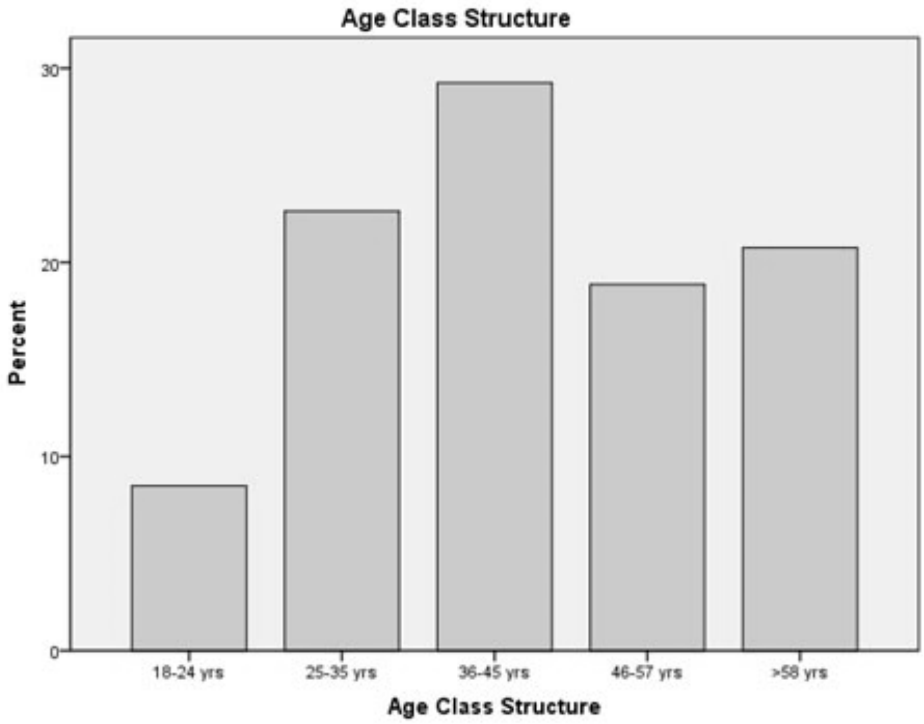

***Figure 3**: Age class structures and use of ethno-medicinal plants in the Buger region*

According to education levels, the highest use of ethno-medicinal plants (traditional medicine) was amongst the people whose highest level of education was primary level (Figure 3). Between those who use ethno-medicinal plants, the percentage who achieved the highest education level at the primary level was 75%. The percentage who used ethno-medicinal plants that had no education was 15%, and those who used traditional medicine whose highest level was secondary school was 10%.

A chi-square determined relationships between gender, education level, and age class structures and use of ethno-medicinal plants. The use of ethno-medicine did not depend upon age class structures (x2= 7.585, p=.108, alpha value= 0.05, not significant). Similarly, the use of ethno-medicine did not depend upon gender (x2= 3.315, p=0.069, alpha value= 0.05, not significant). However, the use of ethno-medicine depended upon education level (x2= 16.105, p=0.003, alpha value=0 .05, significant).

Regarding the medicinal plant knowledge transmission in the community the study found that 75% of those interviewed (80 people) acknowledged young people have less knowledge on ethno-medicinal plants compared to old people.

Popularly medicinal plants found in the community forest

Most of the data were from questionnaires conducted in the village of Buger, several transects were completed in the community forest identifying plant species and their utilizations. Table 4 indicates the popular plants that are often used for medicinal purposes. The most common plant species used for ethno-medicinal purposes was Maslaramo (*Vangaena madagascaneinsis*), which treats several stomach diseases.

Table 4: The availability of ethno-medicinal plants in the Buger community forest.

Local plant species name (Iraqw)	Scientific Name	Frequency of Observation	Percentage
Nughay	*Hoslundia opposite*	4/33	12.1%
Yellow Barked Acacia	*Acacia xanthophloea*	9/33	27.2%
Durang	*Faurea speciose*	19/33	57.5%
Hhangali	*Solanum incanum*	4/33	12.1%
Washawasha	*Senna alata*	1/33	3.0%
Garmo	*Acacia albida*	12/33	36.3%
Meali	*Croton microstachys*	4/33	12.1%
Mori	*Scolopia spp.*	1/33	3.0%
Matsafi	Fagara angolensis	2/33	6.0%
Baryomodi	*Acacia nilotica*	2/33	6.0%
Mgunga	*Acacia spp.*	1/33	3.0%
Ankwi	*Vernonia exsertiflora*	2/33	6.0%

Maslaramo	*Vangaena madagascaneinsis*	25/33	75.7%
Minighiti	*Euclea spp.*	14/33	42.4%
Sandal wood	*Osyris lanceolate*	1/33	3.0%
Msokoni	*Warburgia salutaris*	12/33	36.3%
Mgunga Moto	*Acacia mellyere*	3/33	9.0%

The ethno-medicinal plants supply sources

Although the majority of the informants were not using ethno-medicinal plants, there still is a conservation concern. Of the informants who said "yes" to the use of ethno-medicinal plants, 34 percent of the people said to collect the plants from their yards or areas close to their homes. Fifty-five percent claimed that they collected these plants from the community forest. Ten percent of the informants visited witch doctor or plant herbalist for plant-based medicine. One percent of the informants claimed they grow the plants used for medicine in their yards.

DISCUSSION

Use of ethno-medicine

Based on the results of this study, very few people in the Buger village area are still using ethno-medicinal plants, with the vast majority only relying on modern forms of medicine. Everybody interviewed was benefiting from modern medical services and there was a general consensus among interview members and focus group respondents that ethno-medicinal knowledge was limited to village elders, despite evidence to the contrairy showing no link between age and medicinal plant use. Why would this be the case? For example, Kiringe (2006) notes that for Southern Kajiado District, and many other Maasai communities in Kenya, traditional forms of medicine involving plants are still the primary form of health care. Likewise, Busmann *et al.*, (2006) describes plant knowledge and use as "essential" to Maasai living in Sekenani Valley in Maasai Mara, Kenya. The Ministry of Health and Social Welfare (MOHSW) approximated in 2007 that as many as 60% of Tanzanians seeking health care rely on some form of traditional services (Kwesigabo, 2012). Why does Buger village appear to be an exceptional circumstance?

One possible explanation is that Buger village represents much of the developing world, in that it lies on the cusp of modernity and rural tradition.

As such, there may be in the wake of increasing modernity some kind of stigmatization and/or shame associated with traditional forms of medicine that becomes especially prominent in the presence of white/foreig interviewers. It's therefore unsurprising to imagine that many informants would be embarrassed to admit using medicinal plants and feel pleasure to conform to perceived notions of western healthcare. Despite recent attempts to revive traditional systems of medicine by institutions such as the World Health Organization (WHO), post-colonial national and international policy aimed at revamping healthcare systems in Africa and the colonial 1925 Kenyan "Witchcraft Act" have endured as archetypical examples that showcase traditional systems of medicine as backwards, illegitimate and superstitious under western scrutiny (Kiringe, 2006). On top of that, traditional medicine is a secretive practice to begin with. Knowledge may be diffused throughout the community, but usually there is one individual renowned for their skill, a traditional healer for example, who purposefully convolutes recipes in order to ensure their safekeeping (Sankan, 1995). Although increasing popular use of western medicine is a conceivable reality, it remains unknown if Iraqw are supplementing their healthcare with medicinal plants more than they've revealed. For example, Kiringe (2006) noted that the popularity of herbal remedies has not declined despite the fact that the majority of Maasai in the Southern Kajiado district are also seeking modern medicine. The findings show that although residents consistently voiced their preference for modern medicine and denied medicinal plants use, they still didn't consider them less effective. In fact the majority of respondents (40%), claimed medicinal plants to be mostly and sometimes effective; only 5% said they were ineffective. Therefore, there's a difference between people's perceptions on medicinal plants and what they claim to be using that might be partially explained by a reluctance to tell the truth.

Stigmatization against traditional systems of medicine may be further compounded by the advent of Christianity and higher education. A survey conducted by Pew Forum in 2010 estimated that as high as 60% of the Tanzanian population is Christian (U.S. Department of State, 2012). Christianity, formal education and western colonization are inextricably linked. Maia Green, author of Priests, Witches and Power (2003) "Christian missions in Africa were frequently engaged as contractors to governments for the supply of health and education services, extending the reach and presence of colonial regimes even into remote areas." The lasting consequences of Christian proselytization and political influence have permeated even rural sectors of the countries, causing many Tanzanians to reject traditional religious systems in favor of Christianity. Unfortunately, a historical byproduct of national Christianization is that it leads non-western adherents to culturally dissimilate from previous education and health systems redefined as archaic and illegitimate. Green makes this point clear, “For most European missions in the nineteenth and twentieth centuries conversion to Christianity was viewed as an essential part of global modernization premised on a particular notion of civilization as the culmination of an evolutionary progression away from barbarism and savagery,” (Green, 2003). Therefore, historical and ongoing pressure to adopt elements of western culture advocated as “modern” may be causing Tanzanians to culturally dissociate from earlier strategies used to cope with illness.

That’s why our results showed that indigenous medicinal plant use is dependent upon education level, amongst those who use ethno-medicinal plants, the highest education level achieved was the primary education level (75%). This suggests that possibly with higher education, people are shy to reveal that they use traditional medicine.

Threats to medicinal plants and conservation practices

According to the focus group discussions, there are several climatic factors that could potentially threaten medicinal plant survival. Through matrix ranking, decrease in rainfall (drought) and the loss of wetlands were highly ranked as problems related to climate change. This was followed by an increase in temperature and soil infertility (erosion). Similar to the current study, Lulekal *et al.*, (2008) confirmed that the main threats to the survival of medicinal plants in the Mana Angetu district were agricultural expansion, drought, and soil erosion. Another concern that could potentially affect the conservation of medicinal plants is the utilization of the different parts of the plant. Of the plants that were used for ethno-medicine, the most harvested part of the plant was the bark (35.5%) and the roots (25.8%). A conservation concern is that by harvesting the bark and roots, there is less chance of survival for the entire plant. It was also reported that the majority of the informants that use medicinal plants do not cultivate their own plant species. Results show that 55 percent of the informants who use ethno-medicine collect the plants from the community forest. In order to appropriately ensure the survival of the medicinal plant species, it is important to prevent overuse and establish a better system of collecting plants for medicine.

Limitations of the study

Ethno-botanical data were collected through semi-structured interviews. Although the results showed that 69.8% did not use ethno-medicines, there are several indicators of biased data. The Marang forest, located near the southern part of the community forest, officially became a highly protected forest as part of Manyara National Park in 2008. Prior to 2008, many people relied on the forest resources for medicine, firewood, construction, food, and other sources. During the focus group discussions, the community members mentioned that now the Marang forest is controlled by Tanzania National Parks (TANAPA), many people have lost their source of food, medicine, firewood, and construction materials. People are allowed to use the community forest for these resources; however it requires a permit and the majority of inhabitants in the Buger region collect resources without a permit. It is understandable that many informants may have simply not told the truth when asked about use of plant species for medicinal purposes.

Bush meat study conducted by Martin *et al.* (2012) in Katumba, East Africa, researchers reported to face similar problem. Because bush meat consumption is illegal, it was noted that answers given were not reliable. Concurrent to this study, Mgagwe *et al.*, (2012) conducted a study in Katavi where informants were questioned about bush meat consumption. They discovered that due to the illegality of the consumption of bush meat, many informants were not open to answer whether or not they used bush meat. In a recent study on the consumption of bush meat, out of 81 interviewees, it was reported that 8.6% of the informants had not truthfully answered questions about use of bush meat (Stroming, 2013). Due to these circumstances, it is possible that many of the informants did not say "yes" to the use of ethno-medicine when in reality they use plants for traditional medicine.

CONCLUSION

It is important for the community in the Endabash area to establish an appropriate system for the use of medicinal plants. Simply taking the needed plants from the community forest or local areas will decrease the chance of survival for many of the medicinal plant species. Although the climate change phenomenon has impacted every living organism on the planet, it is important to ensure the survival of medicinal plant species for future use. Over exploitation will lead to extinction of many versatile plant species that are not only used for medicine but also for firewood, construction materials, food, or honey collection. Future studies should focus on identification strategies to replenish diminishing medicinal plant resources, ensuring viable ways for continuous availability and sustainability of such resources.

RECOMMENDATIONS

If the demand for medicinal plants increases, there will be an urgent need to sustain the plant species used for medicine. In order to avoid a rapid decrease in medicinal plants, it is important to establish a management and sustainable utilization system for medicinal plants. The current study showed that in the Buger village there is no established management system for the use of medicinal plants.

It is also important to identify priority medicinal plants for conservation, especially those that largely impact human livelihoods. After identifying key species, appropriate agronomic techniques should be implemented to ensure are planted in their compounds to increase the future availability of the plant species.

Lastly, policy should be enacted that would empower the local people to freely practice traditional medicine in sustainable way. Further pharmacological studies should be carried out on popularly used medicinal plant species to establish their bioactivity potential for developing future drugs to cure certain human diseases.

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THE DISTRIBUTION AND CAUSES OF ALIEN PLANT SPECIES IN SERENGETI NATIONAL PARK

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ABSTRACT

Understanding the factors for the introduction and spread of alien invasive plants is key to their control and management. We assessed the distribution and factors for the spread of alien plant species along 900 km road transects, tourist lodges and woodland areas in the Serengeti National Park (SENAPA) by recording the occurrence of each alien plant species in 10 x 10 m quadrants. The location of each sampling point was tracked using GPS. Descriptive summaries and generalized mixed effects model were used. A total of twenty alien plant species were recorded, whereby six of them which include Amaranthus hybridus, Bidens pilosa, Chromolaena odorata, Opuntia vulgaris, Datura stramonium and Tagetes minuta were frequent. C. odorata, is a known fast invader of grazing lands, the existence of which in the SENAPA threatens the management of grazing land in the ecosystem. Most alien plants were frequently recorded along road sections (due to road grading) and settlement areas (due to waste damping), which was evidence that human disturbance contributed highly to the spread of alien plants in the SENAPA. Understanding how the ongoing human disturbance activities contribute to the spread of some potentially invasive plants in the Park is necessary for managing the spread. Furthermore, there is need for proactive monitoring and control measures which involve community awareness creation before these species become widespread.

Key words: Conservation, Serengeti National Park, alien plants, invasive plants, distribution

INTRODUCTION

The increasing threats from invasive alien plants have triggered adverse environmental and socio-economic effects worldwide. Evidence shows that, landscape structure and land use altogether are driving factors of alien plant invasions (Pauchard and Alaback, 2004;Pauchard and Alaback, 2006;Pauchard *et al.*, 2009). At the land use scale, there are several drivers of plant invasion mainly anthropogenic disturbances (Davis *et al.*, 2000) and increased propagule pressure (Colautti *et al.*, 2006; Pyšek *et al.*, 2009). The colonisation of most alien plant species to human disturbed landscapes clearly indicates the role of humans in accentuating the problem (Hobbs, 2000;Parendes and Jones, 2000). Roadsides serve as reservoirs of propagules that can be liberated in human disturbance events (Parendes and Jones, 2000). Roads save as prime pathways for the introduction of alien plants into protected areas (Suárez-Esteban *et al.*, 2013b; 2013a). Increased population growth, especially along areas adjacent to protected areas increases the demands for settlement areas, which leads to increased disturbances due to construction activities, including road grading. At the landscape scale, elevation gradient was shown as a driving factor for alien plant invasion in forest landscapes (Pauchard and Alaback, 2004;Pauchard *et al.*, 2009).

In Tanzania, some plant invasions are known to be associated with anthropogenic disturbances (Wakibara and Mnaya, 2002), though for some alien plants, rainfall and temperature conditions are main factors (Bukombe *et al.*, 2013b). A survey conducted in the year 2011 in the SENAPA show existence of some alien plant species (Bukombe *et al.*, 2013a). Since then, there have been seasonal exercises conducted by the SENAPA management, through its ecology department to reduce the spread of alien plants. Therefore, the current survey was conducted to: (1) understand the current status of alien plant species, in terms of the richness and spatial distribution in SENAPA (2). Describe major sources of introduction and assess relative contribution of different factors influencing the spread of alien plants in the area. Information generated from this work is imperative to inform the Park management on the existing and potential threats to wildlife conservation in SENAPA. Identifying the main source of introduction and mapping the distribution of alien plant species may help to provide additional critical data for effective planning for wildlife conservation and management in Tanzania. It will also serve as baseline information for ongoing monitoring of the Park, especially on the changes and disturbances from human activities.

METHODS

Study area

The study was done in the central, northern, southern and western parts of Serengeti National Park (SENAPA) (Fig. 1). The Park contains high diversity and concentrations of ungulates, large carnivores, and birds (Sinclair and Arcese, 1995) and the vegetation of the region is highly impacted by the large flocks of migratory wildebeest (*Connochaetes taurinus*), zebra (*Equus burchelli*), Thomson gazelle (*Gazella thomsoni*) (Sinclair &Arcese 1995; Thirgood *et al.*, 2004). Currently, there is evidence for increased tourist activities which have caused improvements and increase of tourist infrastructures such as roads, and construction of settlement buildings in various parts of the Park.

Data collection methods

Alien and invasive plant species were sampled along the roads and human settlement areas in the SENAPA. Alien species were considered as those plant species not native to Tanzania, based on the data base of the National herbarium of Tanzania (TanBIF, 2013). The roads surveyed were 900 km (Figure 1) and were all unpaved, graded to the level of gravel and had enhanced camber to encourage rainwater to drain off roads. Observations were limited to a radius of 100 m on both sides established 20 x 20 m plots (for assessing annual species), within which 10 x 10 m plots were used for assessing perennial plant species). These plots were randomly established at each encounter of an alien plant. The surveyed settlement areas were tourist lodges, including one special camping site. All possible sources of introduction or spread of alien plants were identified. All alien plants in each plot were recorded including the location and elevation of each plot using GPS, Garmin 72. The age classes used were the young plants before flowering; Adult plants at or after flowering and Mixed, when both classes were present) in an area. The frequency of encounter was designated the in an area in three bins depending on the number of times or encounters whereby the species was observed at different locations. The bins were spaced at an interval greater than 2 m apart, based on the species observed in an area. The bins were1 or low (when less than two encounters), 2 or medium (encounters between 2 and 10) and 3 or high (encounters more than 10).

Data analysis

Data obtained was analysed using descriptive summaries and regression analysis. Descriptive summaries were species frequencies of encounter. The main interest was in discovering the influence of each of the different sources of introduction/spread. Generalized mixed effects model with Poisson errors by applying the lmer function in R (Crawley, 2013), to determine the main effects of each source of introduction on alien plant species frequency of occurrence was used. The lmer function used Satterthwaite approximations to degrees of freedom to establish whether any of the sources (factors) affected the spread. The 'frequency classes' was fitted as a response variable and the source factors as treatments (or fixed effects). The 'locality' and 'part' were random effects as defined by the spatial structure. Model fitness was evaluated using chi-squared values ($P < 0.05$).

RESULTS

Five different sources of introduction of alien plant species in the SENAPA were recorded; including: building, decorations, road maintenance, waste dumping and water; which were recorded on roads, settlements and woodland localities. The highest frequency of occurrence and percent cover of alien plants were encountered in settlement areas. Road maintenance was mainly found along roads and including some woodland sites. The mixed effect model with the sources of introduction and elevation treated as fixed variables, indicated that road maintenance ($t = 3.62$, $df = 57.93$, $P = 0.00062$) and waste damping ($t = 3.19$, $df = 196.3$, $P = 0.0164$) significantly influenced the occurrence of alien plants in the SENAPA. The influence of elevation, water flow and decorations were not significant. The spatial difference in occurrence across sites (Central, North, West and South) was higher (variance = 0.42) than the difference between sampling localities (variance = 0.15). When the elevation was excluded, no change occurred in the significance levels for road maintenance ($t = 3.596$, $df = 81.82$, $P = 0.00055$) and waste dump ($t = 3.28$, $df = 197.3$, $P = 0.0012$), but the difference in occurrence between localities slightly increased (variance = 0.20) while was lowered across sites (variance = 0.18).

Alien plant species occurrence varied significantly between the sources ($\chi^2 = 11.16$, $df = 4$, $P = 0.0248$) and localities ($\chi^2 = 9.547$, $df = 2$, $P = 0.0084$) (Figure 3A) using Kruskal-Wallis rank sum test. The highest frequency of occurrence (mean±sd) was encountered in settlement areas (2.4±0.7), followed by roads (2.2±0.82) and was the least in woodlands (1.62±0.52) (Figure 2A); these results were similar to the results for percent cover. The frequently encountered alien plant species were *Amaranthus hybridus, Bidens pilosa, Datura stramonium and Tagetes minuta*, whereby species that were common in all localities include *Amaranthus hybridus* and *Datura stramonium*. *Chromolaena odorata* which is worldwide threat was also recorded in SNP,. Species occurrence was significantly different between the parts or sites ($\chi^2 = 20.887$, $df = 3$, $P = 0.0001$), with the highest mean frequency in the west (2.72±0.45), the least was the north (1.9±0.57). The mean frequency of encounter for the central part was 2.3±0.82 which was relatively lower than the mean frequency for the south 2.4±0.64.

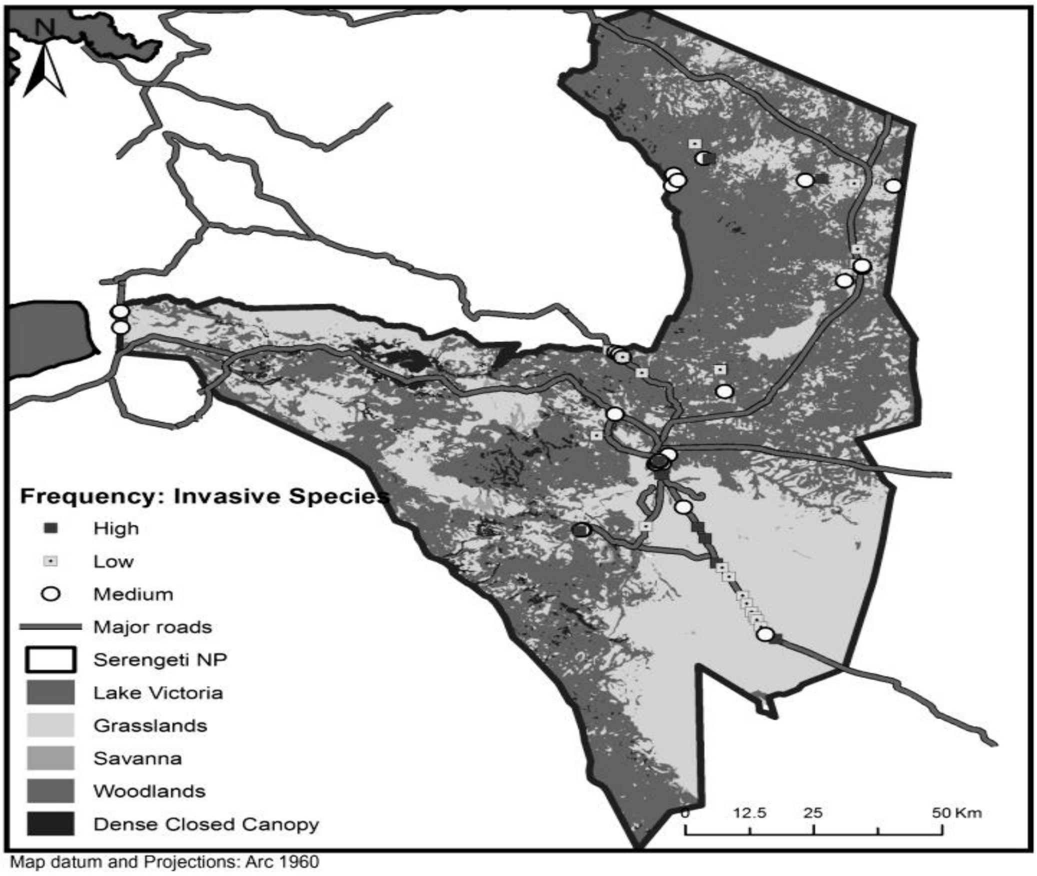

Figure 1: *Map of Serengeti National Park showing the distribution of alien plants in the Central, Northern and Western parts in 2013.*

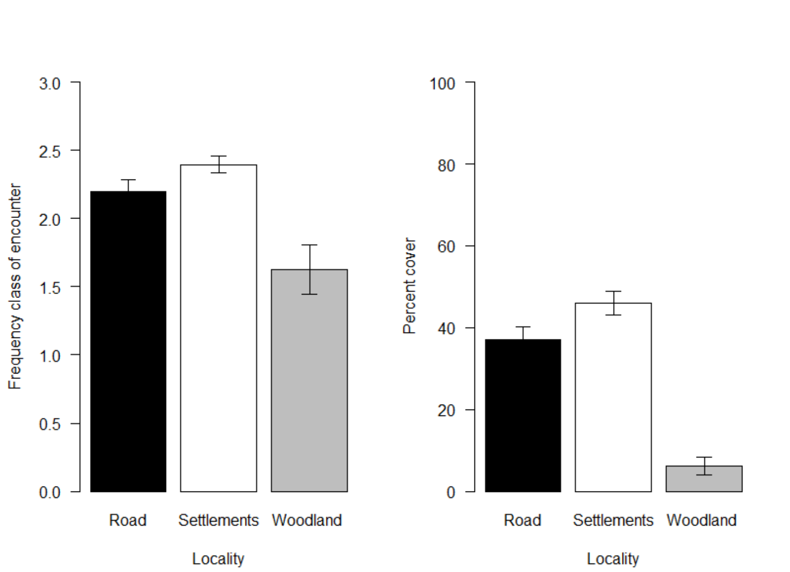

Figure 2*. Frequency of occurrence and cover estimates of alien plants in the three main localities in SNP, in 2013.*

DISCUSSION

Results have revealed that, human activities, which include building, site decorations, road maintenance and waste dumping , are sources of introduction and spread of alien plant species in the SENAPA. Alien plants mainly occurred along road sides, agreeing with Parendes and Jones (2000), that roads are suitable habitats and reservoirs of propagule pressure and are major pathways of alien plants (Tyser and Worley, 1992;Hulme, 2009). In the SENAPA, road maintenance occurred in different settlement localities, grasslands and wooded grasslands, which is an evidence for the existence of alien plants in these areas. The differential occurrence of alien plants indicated the varying extents of the contributing factors, especially the intensity of the sources of introduction. For example, road maintenance was more frequent in the central part and less frequent in the northern parts of the SENAPA, likewise there was a higher occurrence of alien plants along the central road from Naabi towards Fort Ikoma (Figure 1). Disturbance from road maintenance activities help to increase the intensity of exposure , leading to increased light intensity, the outcome of which is increased growth and spread of alien plant species (Parendes and Jones, 2000). A number of studies have demonstrated direct links between number of alien invasive plants and habitat disturbance and/or fragmentation levels (Pauchard and Alaback, 2006).

The fact that waste dumping contributed highly to the spread of alien species in the Park indicated two possible situations: first is lack of awareness amongst the community, regarding the identification of alien plant species and their expected impacts in the ecosystem, the second situation is lack of a known and properly managed mechanism or strategy for waste control and management in the Park. Public awareness is a necessary component in the control and management of alien species (Bremner and Park, 2007), the lack of which may limit the implementation of control and management strategies (Bertolino and Genovesi, 2003), which in turn may affect the level of public support (Manchester and Bullock, 2000).

Elevation gradient was identified as one of the major landscape activities which influenced the invasion process of alien plants (Pauchard and Alaback, 2004;Pauchard *et al.,* 2009). This results revealed very slight correlation between elevation and alien plants occurrence, this was probably due to the fact that this study area included very small range between the highest and lowest elevation measure, which give little chance for differing microhabitats in the area. Studies by Pauchard and Alaback (2004) and Pauchard *et al.* (2009) were conducted at areas with higher elevational ranges, ranging between 0 and at least 1000 a.s.l. These ranges could allow an existence of differing microhabitats.

Though, this study was not aimed at establishing relative invasion success of different alien plant species, the diverse list of alien plant species we encountered along, exposed some species-specific dispersal mechanisms, indicating the need for some specific control strategies (Lipinski and Soll, 2003). For example, some authors show that the control and management of well established populations of *C. odorata* (Uyi and Igbinosa, 2010) vary significantly from that of *P. heysterophorus* (Javaid and Anjum, 2006). In this study, *D. stramonium* is a species which produces floating seeds whereas *X. strumariaum* and *T. minuta* have seeds with hooked projections that are suited for animal dispersal and *A. hybridus* produces thin light seeds with appendages suited for wind dispersal; control and management for all four species should require different strategies. Furthermore, many of the species encountered exhibit self-fertilization, for example *D. stramonium* (Admasu, 2008), *L. camara* (McGranahan *et al.*, 2013), *T. minuta* (Dafni and Heller, 1982) and *C. odorata* (Pheloung, 2001); self-fertilization is a mechanism which help to increase the distribution and spread of the plants.

This study provides only limited species-specific recommendation for management of alien plant species, but some species need prompt attention. Such species include *C. odorata*, a worldwide threat (Zachariades *et al.*, 2010), is known to cause negative impacts on grazing and has been a worldwide target of biological control efforts (Zachariades *et al.*, 2009). Lack of prompt control may cause this species become widespread in the near future. *D. stramonium*, a common weed with well demonstrated allelopathic effect on crops (Levitt *et al.*, 1984) is a prevalent species in both, east and west SENAPA. Therefore, proactive control measures which may be appropriate before their populations expand further is called up on.

CONCLUSION

In general, this study indicated the role of human disturbance on the spread of alien species in protected areas such as the SENAPA. The study further indicated that, a clear understanding of the relations between human disturbances and extent of distribution of some alien plant species may help Park managers in reducing the risk of invasion by setting proper mechanisms for detection and control. The observed prevalence of alien plant species in settlements indicated the lack of community knowledge and awareness of the impacts alien plant in the Park can cause.

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EXISTENCE OF ALIEN PLANT SPECIES IN SERENGETI NATIONAL PARK: A CONSERVATION THREAT

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ABSTRACT

A large portion of the East African landscape is officially protected, yet these areas are increasingly at risk due to plant invasiveness. Roads and settlement areas can serve as prime pathways and reservoirs for alien plants within protected areas. We used stratified ground sampling with the frequency of encounter used to assess the relative influence of human activities to the distribution of alien plant species in Serengeti National Park (SENAPA). Data was analyzed using descriptive summaries and generalized mixed effects model. Results show that four different human activities are sources of spread of alien plants in the SENAPA; these are building, decoration, road maintenance and garbage dumping. The main effects of waste damping and road grading have significant influence on the spread of alien plants. The frequently encountered species are those which have been considered naturalized in Tanzania, including Tagetes minuta, thus may cause little ecological effect. However, encounters of Cromolaena odorata, a worldwide known fast invader, including others which have caused problems elsewhere in the world threatens the biodiversity of the SENAPA.We urge that proactive control and management activities should aim at reducing the spread by focusing at specific activities and sites in the Park.

Key words: Conservation, Serengeti National Park, alien plants.

INTRODUCTION

The increasing threats from invasive alien plants have triggered adverse effects worldwide. The impacts of alien plant species on natural and managed ecosystems is a worldwide environmental and socio-economic problem (Lowe et al. 2000; Brooks et al. 2004; Pyšek and Richardson 2010), because they out compete native species. Research show that ~10% of introduced species will reproduce, of which 10% will form established populations; and 10% of these established populations will become invasive in their new environment (Williamson 1996). Protected areas (PAs) receive a large number of visitors originating from different parts of the globe year-round which increases their vulnerability (Buckley 2004; Foxcroft et al. 2008). Roads through PAs are prime sites of invasion for plants because they represent a contiguous disruption to the ecosystem and are often regularly disturbed. Disturbances are important in creating gaps (safe sites) with bare soil where new individuals can establish (Mazia et al. 2001; Catford et al. 2012). PAs in sub-Saharan Africa are no exception, and invasive alien plants such as Tickberry (*Lantana camara L.*), Spectacular Cassia (*Sena spectabilis* (DC.) H. S. Irwin and R. C. Barneby) and Giant sensitive tree (*Mimosa pigra L.*) are already widely established and problematic in most sub-Saharan countries (Boy and Witt 2013).

Ecologically based invasive plant management requires the implementation of effective detection strategies and requires obtaining the necessary information for prioritizing species especially those which are potentially invasive and sites. Identifying alien plant species and sites prone to invasions in protected areas, provides necessary direction to managers and allows them to prioritise threats and make focused conservation efforts. Protected areas of high conservation value, like Serengeti National Park, require protection that focuses on eliminating or reducing conservation threats such as those due to alien plants. This needs heightened efforts to detect the potentially invasive species and identify potential sources of spread. Like for many sub-Saharan African countries (DNPWSMT 1998; MFW 2011), the Wildlife Policy in Tanzania (Paine and Green 1997; MNRT 1998) considers National Parks as 'pristine' or semi-pristine environments designated to protect their ecological integrity by prohibiting any introduction of alien or non-native fauna and flora in such areas. However, plant invasions have been reported in some protected areas of Tanzania (Sheil 1994; Wakibara and Mnaya 2002; Foxcroft et al. 2006; IUCN 2015). The reasons for the introduction of include ornamental and hedge purposes (Taylor et al. 2012; Boy and Witt 2013) other uses (Wakibara and Mnaya 2002).

Serengeti National Park is one of the leading PAs with the largest tourist facility infrastructure that attracts the highest number of visitors in Tanzania (Eagles and Wade 2006; TANAPA 2013), with around 56 accommodation including 10 lodges and 32 tented camps (Safari-Now 2015). Approximately 40% of time spent by visitors in the Tanzanian National Parks is at lodges in the SENAPA and 43% is in tented camps. In the SENAPA, road grading is conducted as part of management activities. The main roads running through the park connect outside towns and villages where agriculture is central and other human activities are intense (Figure 1). SENAPA conducts frequent exercises to remove any occurring alien plant species within the Park (Pers.Com with Park Ecologists), but the frequent grading of roads as well as human activities in settlement areas may contribute to the recruitment of alien plant species in the Park. In view of this, we were interested to: (1) establish a list of alien plants in Serengeti National Park and (2) evaluate and advice management authorities on the priority areas, sources of spread and species for prompt control in the Park. The results will serve as a baseline for monitoring and control of invasive alien plants in the Serengeti National Park. It will help management authorities to understand the species that are of priority for management actions and this is critical for setting control strategies for effective biodiversity conservation and management in order to maintain the integrity of protected areas.

METHODS

Study area

The study was conducted in the Serengeti National Park (Figure 1). The Serengeti National Park contains large concentrations and a high diversity of ungulates, large carnivores, and birds (Sinclair and Arcese, 1995). Habitat types are varied, including grassland, savanna, closed canopy riverine forest, rocky outcrops, rivers and alkaline lakes, which explain its high diversity in animal species. The south-eastern sector of the Serengeti National Park is open grassland, the northern part is largely wooded while the western region a mix of open and wooded areas. There is a rainfall gradient with increasing precipitation south to north and east to west with parts of the western corridor, which extends to Lake Victoria, receiving >1000 mm and the south-east plains <450 mm. Mean monthly maximum temperature is 27 - 28°C all year round with a mean monthly minimum temperature of 13-16°C (Sinclair and Arcese 1995).

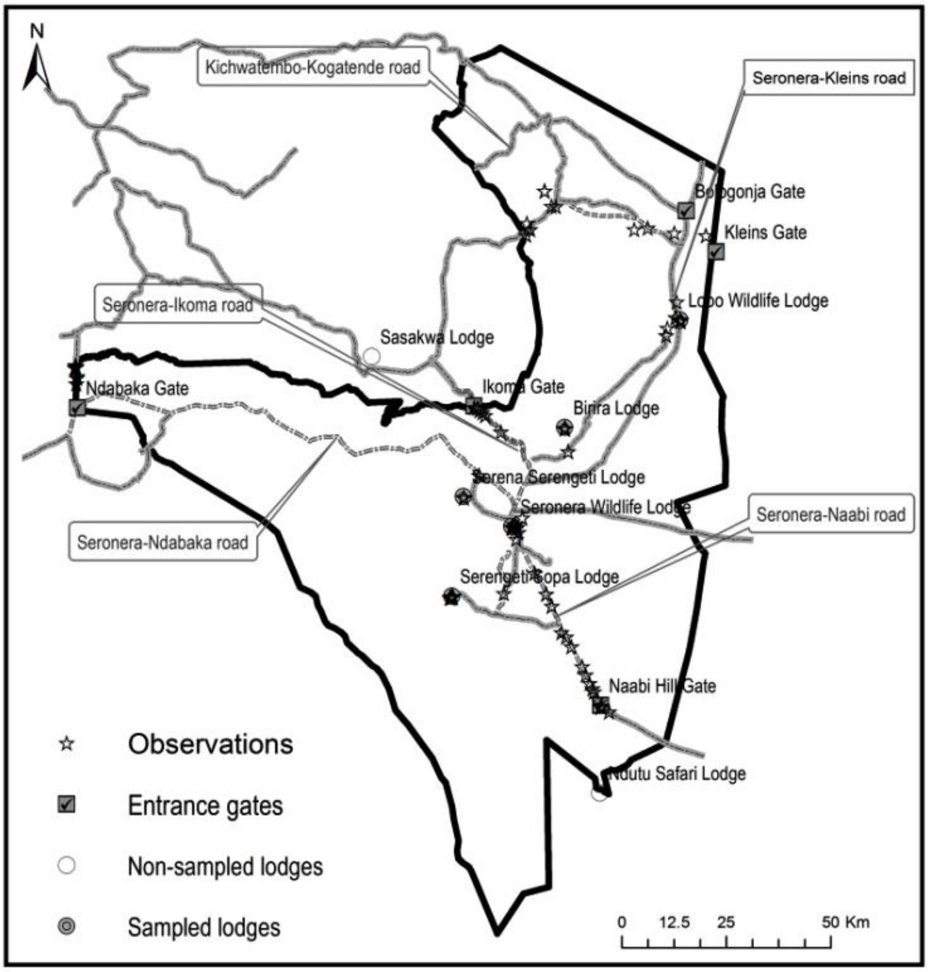

Figure 1: *Map of the Serengeti National Park in 2013 showing points along main roads and settlements on which alien plants were located.*

Under normal circumstances almost all the rain falls in two seasons, a short season (November-December) and a longer one (March-May). However in some years inter-annual variations are inevitable especially due to effects of climate change. The open grassland zone receives rainfall, typically below 600 mm per year. The predominant vegetation in the south is short and long grass plains with the centre characterized by an extensive block of acacia savannah woodland. The western corridor is dominated by wooded highlands and a concentration of wooded grassland is found around tributaries of Grumeti and Mara rivers. There are many small rivers, lakes, and swamps throughout the park. In general, the Serengeti woodlands are mainly composed of Acacia, Balanites and Commiphora species with other broad leaved species such as Terminalia, Euclea and Croton as sub-dominates in some region (Herlocker 1976). The topography is highly variable, with catena effects having an important influence on woody species.

Data collection

Sampling along the main roads was conducted at four main 'parts' of the SENAPA: Central (road section within Seronera area), North (the road section from Lobo through Kleins, Kichwatembo to Kogatende and TaboraB gate), West (the road from Musabi through Ndabaka Gate to Robana bridge) and South (the road section from Hippo pool through Naabi to Olduvai river) of the Serengeti National Park and at five selected tourist lodges including one campsite (Figure 1). The specific sites or 'localities' within parts in which alien plants were assessed are road sides, gardens, dumping places, settlement places, building and construction sites, undisturbed fields (grassland or wooded grasslands) and areas near buildings. Each road was line transect along which sampling was done by stopping every 200 meter and then moving into the field at right angles to the road recording all exotic species within a 5 meter wide transect for 200 meters. This was achieved by referencing the start of transect at the edge of the roadside using a GPS. The six settlements sampled were the Seronera, Sopa, Bilila, Serena Lobo lodges and Bush camp (Figure 1). These lodges were selected because they have existed in the Park for more than five years, which represents a reasonable duration for plant establishment. alien species was defined as any plant species not native to Tanzania according to the data base of the National herbarium of Tanzania (TanBIF 2013). All alien species at each settlement area (lodge/camp) were recorded, irrespective of where they were growing, and then moved out from the lodge edges at a number of compass points using belted line transect recording every exotic species encountered while moving out on that compass bearing for 200 meters. Each encounter of alien plant(s) i.e. a single plant or patch was considered as an independent observation. For herbs and forbs, a patch was differentiated from a single plant if several plants were in groups but separated by less than 30 cm. Stems of shrubs and trees were considered as separate plants. The patch size was visually estimated as the canopy cover proportion of the total plot area and categorized as: 'small' when the proportion was < 5% of the total plot area, 'medium' when between 5 - 50% area and 'large' when it was > 50%.

Data analysis

Data was summarized in tables to indicate the proportional occurrences of alien plants for each source, locality and species. Kruskal-Wallis rank sum test were used to compare frequencies of encounter of alien plants between the sources of spread (and specific localities (construction sites, road sides, gardens, dumping places, lodge/camp and undisturbed areas). The proportions of species encounters were calculated by dividing the number of plots found with alien plants by the total number of plots. To understand the influence of each of the different sources of introduction/spread, we considered each random sample plot a split-plot. We then used a generalized mixed effects model with Poisson errors in R (Crawley 2013), to determine the main effects of each source of introduction on alien plant species frequency of occurrence. We used Satterthwaite approximations to degrees of freedom to establish whether any of the sources (factors) affected the spread. The 'frequency classes' was fitted as a response variable and the source factors as treatments (or fixed effects). The 'locality' and 'part' were random effects as defined by the spatial structure. Model fitness was evaluated using chi-squared values ($P < 0.05$).

RESULTS

Agents and specific localities of spread of alien plants in the Serengeti National Park

The five source categories of introduction (spread agents) of alien plant species in the SENAPA include: building, decorations, road maintenance, Garbage/waste dumping and water, whereby the contribution of each source was observed at specific localities where alien plants were recorded (Table 1).

Table 1: The proportional contribution to the spread of alien plant species by some agents at specific localities identified in 2013 in the Serengeti National Park

Source (Spread Agent)	Locality (specific sites)	Proportion (%) along Roads (n = 104)	Proportion (%) in Settlements (n = 104)	Grand Total proportion (n = 104)
Building	Construction sites		10.58	10.58
	Dump		9.62	9.62
	Garden		13.46	13.46
	Lodge/Camp	5.77	28.85	34.62
Decoration	Dump		0.96	0.96
	Garden		11.54	11.54
	Undisturbed places		1.92	1.92

Source (Spread Agent)	Locality (specific sites)	Proportion (%) along Roads (n = 104)	Proportion (%) in Settlements (n = 104)	Grand Total proportion (n = 104)
	Road side		1.92	1.92
	Lodge/Camp		1.92	1.92
Road maintenances	Dump	0.96		0.96
	Undisturbed places		1.92	1.92
	Road side	39.42	43.27	82.69
	Lodge/Camp	2.88	0.96	3.85
	Undisturbed places	7.69		7.69
Garbage dump	Dumping sites		5.77	5.77
	Lodge/Camp		1.92	1.92
Water flow	Garden		0.96	0.96
	Lodge/Camp		3.85	3.85
Mean		**9.4**	**8.7**	**11**

Along roads away settlements, only building and road maintenance were identified as source categories, but all five categories occurred at settlement areas. For each category, specific sites or localities at which alien plants were recorded (Table 1). The frequency of occurrence of alien plants varied significantly between the sources/agents of spread (χ^2 = 11.16, df = 4, P = 0.02) and the specific localities/ sites (χ^2 = 9.547, df = 2, P = 0.01) using Kruskal-Wallis rank sum test. The mean occurrence of alien plants along roads was 9.4% and was 8.7% for settlements while the overall mean was 11%. Using the frequency of occurrences of alien plants, we obtained significant main effects of road maintenance (t = 3.62, df = 57.93, P = 0.001) and waste damping (t = 3.19, df = 196.3, P = 0.01). The occurrence across sites (Central, North, West and South) varied by the variance of 0.42 higher than the variance for difference between localities which was 0.15. When elevation was excluded from variables the analysis, the statistical results did not change for road maintenance (t = 3.596, df = 81.82, P = 0.001) and waste dump (t = 3.28, df = 197.3, P = 0.001), but the variance difference between localities decreased to 0.18 while the variance difference between sites increased to 0.18.

Table 2 Frequency of encounter and proportional contribution to the spread by specific alien plants in 2013 in Serengeti National Park

Common name	Scientific name	Road Proportion (n = 104)	Settlement Proportion (n = 104)	Road and Settlementcombined Proportion (n = 104)
Henequen	*Agave fourcroydes* Lemaire		0.96	0.96
Sisal	*Agave sisalana* Perrine		1.92	1.92
Blue agave	*Agave tequilana* F. A. C. Weber.		7.69	7.69
Female finger	*Amaranthus hybridus var.hybridus* L.	7.69	12.50	20.19
Mexican Prickly poppy	*Argemone Mexicana* L.	1.92	3.85	5.77
Blackjack	*Bidens pilosa* L.	6.73	13.46	20.19
Coffee senna	*Cassia occidentalis* L.	2.88	0.96	3.85
Siam weed	*Chromolaena odorata* (L.) King & H.E. Robins.	2.88		2.88
Thorn apple	*Datura stramonium* L.	4.81	28.85	33.65
Upland cotton	*Gossypium hirsutum* L.	1.92		1.92
Tick berry	*Lantana camara* L.	1.92	1.92	3.85
Prickly pear cactus	*Opuntia ficus-indica* (L.) Mill.	7.69	17.31	25.00
Castor bean	*Ricinus communis var.africanus* L.	1.92	9.62	11.54
Stinking Roger	*Tagetes minuta* L.	12.50	29.81	42.31
Rough cocklebur	*Xanthium strumarium* L.	3.85	3.85	7.69

Note: *The sign * represents the species has high potential for invasion. An empty cell represents the respective alien species was not recorded*

The proportional occurrence of common alien plants in Serengeti National Park

Overall, the frequently encountered alien plant species were *Tagetes minuta, Amaranthus hybidus, Bidens pilosa, Opuntia ficus, Ricinus communis and Datura stramonium* (Table 1). A notorious weed *Chromolaena odorata* was frequently encountered in settlement areas but within borders of SENAPA.

DISCUSSION

This study provides for the first time insights regarding on the responsible sources and specific sites prone to initial plant invasion by exotic species in protected area, especially the Serengeti National Park which has been little studied. We show that anthropogenic activities occurring along roads are responsible in the process of spread of alien plants in SENAPA. Road grading and maintenance form one of major activities in the SENAPA, and occur at main roads and roads within settlement localities. Disturbance from road maintenance activities help to increase the intensity of exposure , leading to increased light intensity, the outcome of which is increased growth and spread of alien plant species, agreeing with previous work that roads are suitable reservoirs of propagule pressure (Parendes and Jones 2000) and major pathways of alien plants (Menard 2002; Schmidt et al. 2015). High occurrence of alien plants at settlement areas also suggests the influence human disturbances, other than road maintenance on the spread of alien plants in the SENAPA. A number of studies have demonstrated direct links between number of alien plants and habitat disturbance and/or fragmentation levels (Pauchard and Alaback 2006).

Statistically, waste dumping had a significantly high occurrence of alien plants in the Park, which could be due to: (1) is lack of awareness especially regarding expected impacts, (2) is lack of proper management mechanism or strategy for waste control and management in the Park. Public awareness is a necessary component in the control and management of alien species (Olff and Ritchie 1998), the lack of which may limit the implementation of control and management strategies (Olff and Ritchie 1998), which in turn may affect the level of public support (Bragg and Hulbert 1976).

This work was not aimed at establishing relative invasion success of different alien plant species, the established list of alien plant species in the SENAPA, though not exhaustive for the whole park, could indicate that control and management would require a combination of different strategies. This is because the different species should have specific dispersal mechanisms, as was pointed out by Lipinski and Soll (2003). For example, the control and management of well established populations of *C. odorata* (Uyi and Igbinosa 2010) vary significantly from that of *P. heysterophorus* (Javaid and Anjum 2006). Most alien plants established by this study are those which have been naturalized following their introduction long ago in Tanzania. For example T. *minuta, X. strumariaum* and *R. communis* often grow on disturbed non-protected land across the country but their ecological impacts are inconsequential at the moment. However, some species such as *C. odorata*, *O. ficus var indica*, *L. camara* and *D. stramonium* need prompt attention, because they have been demonstrated to cause negative ecological impacts elsewhere. For example, *C. odorata*, a worldwide threat (Zachariades et al. 2010), is known to cause negative impacts on grazing and has been a worldwide target of biological control efforts (Zachariades et al. 2009). Lack of prompt control may cause this species become widespread in the near future. Furthermore, *D. stramonium*, a common weed with well demonstrated allelopathic effect on crops (Roder et al. 1996) is a prevalent species both in the east, west and SNP. Therefore, proactive control measures which may be appropriate before their populations expand further.

Overall, this study has clearly elicited human activities (sources) and specific sites of spread of alien plants in the SENAPA. The study further demonstrated the specific alien plant species that need critical attention for control and management and the need for community awareness on such species and their expected negative impacts.

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FOREST EDGE EFFECTS FOR THE THREE GLADE TYPES IN ARUSHA NATIONAL PARK

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ABSTRACT

Forest edges have conservation value due to differences in plant species composition, richness and diversity based on the habitat characteristics. This study characterized and compared the forest edge effects of five man-made, five upper and 15 lower natural glades in the Arusha National Park. The plant species composition differed significantly between the three glade types. The edge effect was observed between 12.5 - 22.5 and 42.5 - 52.5 meters from the forest edge into the forest interiors of lower and upper natural glades respectively.

Eight plant species (Selaginella kraussiana, Plectranthus elegans, Cynoglossum coeruleum, Bersama abyssinica, Asplenium bugoiense, Nuxia congesta, Carrisa edulis and Clutia abyssinica) were found to be indicator species along the forest edge of upper natural glades, one species (Diospyros abyssinica) were indicator of lower natural glades and three species (Solanum incanum, Croton macrostachyus and Teclea nobilis) were indicators of man-made glades. In summary, natural glades and their edges have high plant conservation value as compared to man-made glades due to high plant species abundance, richness and diversity and this rate the conservation value of man-made glades to be low. Therefore, clearing of plants from the forest edges of man-made glades does not in itself contribute to plant biodiversity, although forest-edge plant composition, diversity and richness contributes to ecosystem heterogeneity which supports wildlife conservation.

Keywords: Conservation value, edge effects, glade types, indicator species,

INTRODUCTION

In continuous forests and woodland habitats of East Africa, treeless, open grassland patches, or glades, can be found as relatively permanent landscape mosaic communities that increase ecosystem heterogeneity (Young *et al.*, 1995). In the Laikipia ecosystem of Kenya, glades in acacia bushland and woodland communities are reportedly in old settlement sites of traditional pastoralists (Young *et al.*, 1995; Herren, 1987). Kahana *et al.*, 2013; 2013 reported differences in vegetation types in the forest, forest edge and glades of man-made, upper natural and lower natural in Arusha National Park. Edge effects differed in depth and sharpness, with plant species richness and diversity being lowest inside glades and gradually increasing with distance from the glade interior towards forest-glade edges (Kahana *et al.* 2013; 2013). The forest or woodland edge reflects demographic influxes of individual plant species, each with a distinctive life history and physical requirements, which translate into unique edge zone distributions (Matlack and Litvaitis, 1999). Thus, in contrast to the interior, forest or woodland edges are associated with greater species richness including edge specialist species (Matlack and Litvaitis, 1999; Murcia, 1995).

The spatial nature of heterogeneity differ depending on species distribution relative to glade types. This is determined by plant composition and structure that influence the distribution and diversity of birds and mammals in the glades and surrounding forest (Kahana *et al.*, 2013; 2013).

In addition, plant abundance and vegetation type at the edges shows considerable variation among sites ecological successional (Matlack and Litvaitis, 1999). Forest edges are typically hotter, drier, windier, and sunnier than the forest interior because they are exposed to more sunlight and air heated in the grassland clearing (Murcia, 1995). These micro-enıvironmental changes at the edges may have a significant impact on the resources, e.g. an increase in plant diversity at the edge will attract a high number of animals to forage (Gutzwiller and Anderson, 1992; Murcia, 1995). The character of the edge vegetation also strongly influences the edge zone. For example, in forests the microclimate is controlled by the crown canopy, whereas in clearings the soil is the thermodynamically active surface controlled by temperatures (Harris, 1988; Murcia, 1995; Turner, 1996; Degraaf and Miller, 1996; Zuidema *et al.*,1996; Baker *et al.*, 2002). Herbaceous species also have similar light response, characterized by increased densities of light-demanding species near the edge (Gutzwiller and Anderson, 1992; Matlack, 1994; Murcia, 1995).

The changes in plant composition and structure at the edges will thus, influence animal and bird distributions (Harris, 1988, Terborgh, 1992; Murcia, 1995; Turner, 1996; Malcolm, 1999; Fahring 2003). Ungulates are attracted to habitats because of plant composition and structure (Matlack and Litvaitis, 1999; Fink *et al*., 2006).. Herbivores prefer the habitat edges because of the higher structural complexity, more varied composition and greater availability of food (Matlack and Litvaitis, 1999).

Glades provide valuable habitats for a wide range of domestic and wildlife species. Glades located in the forest matrix differ in plant communities and hence, influence the pattern of resource use by animal species using the glades, the surrounding forests or both (Kahana *et al*., 2013). Glade edges provide an abundant amount and wide variety of shrubs and trees for browsers, shelter for ungulates against predators, and ungulates may use the glades for locating water and mates (Pratt and Gwynne, 1977; Shaw, 1985).

At the Arusha National Park, there are three glade types of different sizes found in dissimilar, although adjacent habitats. This provides an ideal area to study the plant species composition, distribution, abundance and diversity in glades of different sizes and in different glade types. The objectives of the study were to 1) characterize the glades (in regard to glade size, altitude, and nearest neighbor); 2) determine forest-edge plant composition, abundance, structure, richness and diversity at the forest-edge; and, 3) determine the biodiversity and conservation value of the plants at the forest-edge for each glade type. The overall goal of the study was to compare forest edge effects for the three glade types and provide a recommendation as whether man-made glades should be actively managed (*status quo*) to conserve plant species or if they should be allowed to revert back to forest.

MATERIALS AND METHODS

Study Site

The study was conducted at Arusha National Park, located at 03° 16’ to 03° 20’ S; 36° 45’ to 36° 53’ E on the eastern slopes of Mount Meru. The park is 552 km^2 in size and is mountainous with elevations ranging from 1,400 to 4,566 meters above sea level (m.a.s.l.). The habitats of the reserve include evergreen forest, secondary forest, shrub land, wetlands and glades (Mangubuli and Lyamuya, 1988).

Arusha National Park, has a total of 33 glades: 6 man-made, 21 lower natural and 6 upper natural. Lower natural glades were formed as a result of movement of masses of water, mud, rocks, and lava that cascaded down the eastern side of the Mount Meru and support grass growth (Guest and Leedal, 1953). The soil of upper natural glades is shallow with a rocky surface substratum that supports grass growth. Man–made glades were created in the year 1986 by clearing the forest edge trees and shrubs. The clearance was done by expanding small portions of open grassland in the forest into large open grassland habitat for easy observation of forest animals during game viewing and hunting. Currently, are managed for biodiversity conservation, ecotourism (game and bird viewing, walking safaris and campsites), field laboratory training for students, and research in the field of wildlife management and conservation.

Rivers Jamari and Baribari flow through the park near all of the glades. The park has two rainy seasons: a short season between October and December, and a long rainy season between March and June. Annual rainfall ranges between 1,300 to 2,400 mm. The annual mean maximum temperature is 25.4 ^{o}C and the annual mean minimum temperature is 12.8^{o}C. Lower natural glades are maintained by flooding during the rainy seasons, and natural glades are maintained by grazing animals; while man-made glades are maintained by grazing animals, as well as periodic slashing to remove the encroaching trees and shrubs. Common mammals found in the Arusha National Park, include: Common warthog (*Phacochoerus aethiopicus*), African elephants (*Loxondota africana*), African buffalo (*Syncerus caffer*), Common duiker (*Sylvicapra grimmia*), Leopard (*Pathera pardus*), Giraffe (*Giraffa camelopardalis*), Bushbuck (*Tragelaphus scriptus*), Waterbuck (*Kobus ellipsiprymnus*), Mountain reedbuck (*Redunca fulvorufula)*, Olive baboons (*Papio anubis*), Vervet monkeys (*cercopithecus aethiops*), Blue monkeys (*Cercopithecus mitis)*, and Black-and-white colobus monkeys (*Colubus guereza*) (Assad, 1987).

Data collection

The research design followed a three-way comparison of glade characteristics, and vegetation structure of the forest-glade edge for the three glade types. A total of 25 glades were randomly selected: five man-made, 15 lower natural and five upper natural.

Vegetation surveys were conducted by randomly setting up seven plots (10 m x 5 m = 50m^2): starting at 2.5, 12.5, 22.5, 32.5, 42.5, 52.5 and 62.5 m from the forest-glade edge into the forest. Vegetation structure within each plot was classified in terms of growth forms according to Edwards (1983) and plants were identified to the species level (Okwaro, 1994). Plant total abundance, percent basal cover, species richness, and species diversity were determined for each plot, as well as percent canopy cover and tree diameter at breast height (DBH).

Data Analysis

Glade size, glade altitude and distance to nearest neighbor were compared for the three glade types using Kruskal-Wallis ANOVA. Plant total abundance, percent basal cover, species richness and species diversity and percent canopy cover for the seven forest plots, were compared within and between the three glades types using one-way ANOVA to test the effect of glade type on vegetation structure. Shannon-Wiener (SW) diversity index (H') was used to calculate plant species diversity (Zar, 1984). Forest plant total density (stem/hectare), species richness and heterogeneity for the three glade were calculated. Species richness, total abundance, basal cover, and proportional plant cover for each of the five growth forms (grass, forbs, dwarf shrub, shrubs and trees), were compared between the three glade types using one-way ANOVA. Post-hoc comparisons (Least Significance Difference (LSD) were performed to determine how deep the edge effects penetrated into the forests bordering the three glade types. Chi–square analyses were used to determine if different plant growth forms were associated with forest edge or interior habitats. Multiple Response Permutation Procedure (MRPP) was used to test for group differences in plant species composition between man-made, lower natural and upper natural glades, as well as within group homogeneity (Mccune and Mefford 1999). Indicator species analysis was used to detect and describe the value of plant species as a habitat indicator in the forest edge or forest interior. Indicator species are species that are abundant and frequently sighted in a given habitat (Mccune and Mefford, 1999). This analysis combines information on relative abundance and frequency of each species in a particular habitat to produce and indicator value that ranged from zero to 100 with 100 being a perfect indication).

RESULTS

Glade size, altitude and nearest neighbour distance (NND)

Data for glade size, altitude and distance to nearest neighbour for all three glade types are listed in Table 1. As shown in Table 2, glade size and nearest neighbour distance did not differed significantly between the three glade types. However, the altitude of the three glades types did differ significantly with upper natural glades being the highest above sea level.

Table 1. Glade characteristics for the three glade types: glade sizes, altitudes and distances tonearest neighbors (nearest glade name).

Table 1: Glade type, size, altitude and distance to nearest neighbour

Glade name	Glade type	Size (m^2)	Altitude (m)	Nearest neighbor distance (m)*
1	Lower natural	7,679	1,617	2,820 (2B)
3A	Lower natural	6,092	1,626	1,560 (15)
3B	Lower natural	33,309	1,615	440 (3A)
3C	Lower natural	5,667	1,613	30 (3B)
7	Lower natural	6,403	1,617	120 (3C)
9	Lower natural	8,240	1,666	10 (10)
10	Lower natural	3,568	1,658	1,260 (19)
11	Lower natural	9,463	1,639	820 (9)
12	Lower natural	17 795	1,614	960 (3D)
13B	Lower natural	32,835	1,706	350 (13A)
14A	Lower natural	26,524	1,675	820 (16)
14B	Lower natural	2,282	1,683	450 (15)
26	Lower natural	3,345	1,714	1,600 (14A)
19A	Lower natural	7,733	1,687	70 (19B)
19B	Lower natural	3,453	1,684	2 270 (G9)
22	Upper natural	2,975	2,003	220 (25)
25	Upper natural	3,239	2,045	350 (G27)
27	Upper natural	13,108	2,076	400 (29)
28	Upper natural	2,068	2,070	300 (29)
29	Upper natural	3,037	2,103	300 (28)
2A	Man-made	11,677	1,473	2,090 (9)
2B	Man-made	1,102	1,479	190 (2A)
3D	Man-made	21,405	1,617	340 (3B)
13A	Man-made	9,876	1,678	880 (26)
15	Man-made	32,344	1,618	170 (1)

**words in brackets indicates the name of the nearest glade.*

Table 2: Differences between glade size, altitude and nearest neighbor distance between three glade types

Glade Type	Lower natural (mean+/- standard deviation)	Upper natural (mean+/- standard deviation)	Man-made (mean+/- standard deviation)	Df	Kruskal-Wallis ANOVA
Size (m^2)	11,627 ± 10,979	4,885 ± 4619	15,281 ± 11,957	2	0.12
Altitude (m)	1,654 ± 36	2059 ± 38	1573 ± 92	2	0.00*
Nearest neighbor distance (m)	905 ±357	314 ± 67	734 ± 332	2	0.47

*$p<0.05$

Forest-Edge and interior vegetation

A total of 162 plant species were recorded in the forest of the three glade types (Table 3). Of these, 88 plant species were found in more than one glade type, as follows: 43 in all three glade types, 26 in lower natural and man-made glades, 19 in lower and upper natural glades, and five in the man-made and upper natural glades. Seventy plant species were found only in a single glade type, with 35, 19 and 16 in lower natural, man-made and upper natural, respectively (Table 3).

Table 3. List of 162 plant species recorded in the forest of man-made (MM), upper natural (UN) and lower natural (LN) glades

Species	Growth form	MM	UN	LN
Albiziaspp.	Tree	v		v
Bersama abyssinica	Tree	v	v	v
Bridelia micrantha	Tree	v	v	v
Brideliaspp.	Tree			v
Canthium keniensis	Tree	v		v
Canthiumspp.	Tree			v
Cassipourea malosana	Tree			v

Species	**Growth form**	**MM**	**UN**	**LN**
Clausena anisata	Tree	v	v	v
Conopharyngia usambarensis	Tree	v	v	v
Croton macrostachyus	Tree	v		v
Croton megalocarpus	Tree	v		v
Diospyros abyssinica	Tree	v	v	v
Euclea divinorum	Tree	v	v	v
Euclea schimperi	Tree		v	v
Euphorbia spp.	Tree			v
Fagaropsis angolensis	Tree			v
Ficus thonningii	Tree		v	v
Hagenia abyssinica	Tree		v	
Nuxia congesta	Tree		v	
Olea Africana	Tree	v	v	v
Olea capensis	Tree		v	
Olea hochstetteri	Tree		v	v
Olea welwitschii	Tree		v	v
Peddiea volkensii	Tree		v	v
Pterocarpus angolensis	Tree	v		
Rauvolfia caffra	Tree	v		v
Rhamnus prinoides	Tree			
Tabernaemontana usambarensis	Tree		v	v
Teclea nobilis	Tree	v	v	v
Teclea simplifolia	Tree			v
Trichilia emetica	Tree	v		v
Turraea robusta	Tree		v	v
Zanthoxylum chalybeum	Tree	v	v	v
Zanthoxylum usambarensis	Tree			v
Cynodon dactylon	Grass	v	v	v
Cynodon plectostachyus	Grass			v

Species	Growth form	MM	UN	LN
Cyperus distans	Grass-sedge			v
Cyperus laevigatus	Grass-sedge		v	v
Cyperus*spp.*	Grass-sedge	v	v	v
Cyperus rotundus	Grass-sedge			v
Digitaria scalarum	Grass	v		v
Digitaria velutina	Grass	v	v	
Eleusine jaegeri	Grass	v	v	
Eragrostis tenuifolia	Grass	v		
Heteropogon contortus	Grass	v		
Kyllinga errecta	Grass	v	v	v
Kyllinga rotunda	Grass			v
Oplismenus hirtellus	Grass		v	
Panicum maximum	Grass		v	
Panicum trichocladus	Grass			
Paspalum commersonii	Grass		v	
Setaria chevalieri	Grass	v	v	
Setaria hirta	Grass		v	v
Setaria homoyma	Grass	v	v	v
Setaria megaphyllai	Grass	v	v	v
Setaria phragmitoides	Grass		v	v
Setaria plicatilis	Grass			v
Setariaspp.	Grass	v		
Setaria sphacelata	Grass		v	v
Sporobolus africanus	Grass	v		v
Themeda triandra	Grass	v		
Senna didymobotrya	Dwarf-shrub	v	v	v
Senna mimosoides	Dwarf-shrub		v	v
Senna obtusifolia	Dwarf-shrub	v		v
Senna spectabilis	Dwarf-shrub	v		v

Species	**Growth form**	**MM**	**UN**	**LN**
Vernonia auriculifera	Dwarf-shrub			v
Vernonia brachycalyx	Dwarf-shrub	v		v
Vernonia galamansis	Dwarf-shrub	v		v
Vernonia pauciflora	Dwarf-shrub			v
Caesalpinia decapetala	Shrub			v
Capparis tomentosa	Shrub	v		
Carrisa edulis	Shrub	v	v	v
Clausena anisata	Shrub		v	
Clerodendrum johnstonii	Shrub	v	v	v
Clutia abyssinica	Shrub	v	v	v
Coffea arabica	Shrub	v		
Crotolariaaxillaris	Shrub			v
Crotolaria agatiflora	Shrub	v		v
Crotolaria kirkii	Shrub			v
Crotolaria lebrunii	Shrub		v	
Crotolariaspp.	Shrub			v
Crotolaria spinosa	Shrub		v	
Cyathula cylindrical	Shrub			v
Hibsicus vitifolius	Shrub	v		
Jasminum abyssinicum	Shrub	v		
Jasminum oblongfolium	Shrub	v		
Lippia javanica	Shrub	v	v	v
Microglossa oblongfolia	Shrub	v		v
Ocimum suave	Shrub	v		v
Psiadia arabica	Shrub	v		v
Rubus volkensii	Shrub	v	v	v
Sida ovate	Shrub	v		
Solanum aculeatissimum	Shrub		v	v
Solanum incanum	Shrub	v	v	v

Species	Growth form	MM	UN	LN
Toddalia asiatica	Shrub	v	v	v
Trichodesma zeylanica	Shrub	v		
Vangueria acutiloba	Shrub	v		
Acalypha volkensii	Forbs	v		v
Acanthus amirens	Forbs			v
Ageratum conyzoides	Forbs	v		v
Amaranthus spp.	Forbs	v		v
Archyranthes aspera	Forbs	v	v	v
Artemisia afra	Forbs	v		
Asparagus africana	Forbs	v		v
Asparagus asiatica	Forbs			v
Asplenium bugoiense	Forbs		v	v
Asplenium strangeanum	Forbs	v	v	v
Asystasia gangetica	Forbs	v	v	v
Becium angustifolium	Forbs			v
Becium obovatam	Forbs		v	
Carduus nyassanus	Forbs		v	
Caucalis incognita	Forbs	v	v	v
Coccinea trilobata	Forbs		v	
Commelina benghalensis	Forbs	v	v	v
Commelina petersii	Forbs	v	v	v
Conyza floribunda	Forbs			v
Cucumis aculeatus	Forbs	v		v
Cyathula cylindrica	Forbs		v	v
Cyathula polycephala	Forbs		v	
Cynoglossum coeruleum	Forbs	v	v	v
Cyphostemmaalecaule	Forbs		v	
Cyphostemma adenocaule	Forbs	v	v	v
Cyphostemma colearum	Forbs	v	v	v

Species	Growth form	MM	UN	LN
Cyphostemma hirtellus	Forbs			v
Dichondra repens	Forbs	v	v	v
Dolichos axillaris	Forbs			v
Dolichos latifolia	Forbs			v
Dolichos oliveri	Forbs	v		v
Drymaria cordata	Forbs	v		v
Dryopteris anthamantica	Forbs	v		
Euphorbia hirta	Forbs			v
Girardinia diversifolia	Forbs	v	v	v
Hibisicus vitifolius	Forbs	v	v	
Hypoestes verticillaris	Forbs		v	v
Impatiens digitata	Forbs			v
Impatiens nana	Forbs	v	v	v
Indigofera errecta	Forbs	v		
Justicia betanica	Forbs	v		v
Justicia flava	Forbs	v	v	v
Justicia gangetica	Forbs		v	v
Justicia keniensis	Forbs			v
Justicia striata	Forbs	v		
Kalanchoe densiflora	Forbs	v	v	v
Leonotis nepetifolia	Forbs	v		v
Leonotis mollissima	Forbs	v		
Momordica boivinii	Forbs			v
Momordicaspp.	Forbs			v
Oxalis cordifolia	Forbs		v	v
Oxalis latifolia	Forbs			
Pellaea calomelanos	Forbs	v	v	v
Pentas lanceolata	Forbs	v		
Piper capensis	Forbs			v

Species	Growth form	MM	UN	LN
Plectranthus caninus	Forbs			v
Plectranthus elegans	Forbs	v	v	v
Rhynchosia minima	Forbs	v	v	
Salvia nilotica	Forbs			v
Scadoxus multiflora	Forbs		v	
Selaginella kraussiana	Forbs		v	v
Seneciospp.	Forbs		v	
Trichodesma zeylanicum	Forbs	v		v
Triumfetta rhomboiclea	Forbs		v	
Urtica massaica	Forbs	v	v	v

The different forest plant growth forms of different trees, shrubs, dwarf shrubs, forbs, and grasses recorded were not associated with edge or interior forest habitat for upper natural glades ($\chi2$ = 9.52, df = 8, P = 0.30) and man-made glades ($\chi2$ = 13.89, df = 8, P = 0.09). However, plant growth forms of species recorded were associated with forest edge or interior habitat for lower natural glades ($\chi2$ = 15.58, df = 8, $P < 0.05$).

Forest plant total density (stems/hectare) was highest in upper natural glades (36,800), high in lower natural (22,700) and lowest in man-made glades. Species richness and diveristy was highest in lower natural (n = 128 and H' 2.98 respectively), high in man-made (n = 97 and H' 2.68 respectively), and lowest in upper natural glades (n = 86 and H' 2.44 respectively). Upper natural was the most heterogeneity (0.52, followed by man-made (0.42) and least in lower natural (0.30).

The plant species composition in the forest of man-made, upper and lower natural glades differed significantly between habitats, i.e. the habitat occupy different region of species in space (MRPP; $T = -6.13$, $A = 0.20$, $p < 0.001$). Forest edge in this study refers to the interface between forest and glades, whereas forest interior refers to a forest that show no detectable edge influence and edge/interior refer the interface between edge and interior forest habitat (Harper *et al*., 2005). Indicator plants are plants that indicates habitat condition.

Edge effects and distance into the forest

In both upper and lower natural glades, percentage plant basal cover changed significantly with distance into the forest ($F_{(6,28)} = 2.80$, $p < 0.05$) and ($F_{(6,98)} = 2.36$, $p < 0.05$ respectively) Post-hoc comparison (LSD, $p < 0.01$) indicated that in upper natural glades, this edge effect was prevalent between 42.5 m and 52.5 m and Lower natural glades, this distance was 12.5 and 22.5 m (Fig. 1). No edge effect was noted in the man-made glades. In upper natural glades, the total abundance of shrubs ($R = -0.03$, $p > 0.05$, $n = 11$) and dwarf shrubs ($R = -0.01$, $p > 0.05$, $n = 3$), and basal cover of dwarf-shrubs ($R = -0.01$, $p > 0.05$, $n = 3$) decreased with distance into the forest. In upper natural glades, shrub species richness differed significantly with distance into the forest $F_{(6,28)} = 2.12$, $p < 0.05$. and lower natural glades, dwarf shrub total abundance and percentage basal cover differed significantly with distance into the forest $F_{(6,98)} = 2.44$, $p < 0.05$ and $F_{(6,98)} = 2.50$, $p < 0.05$ respectively.

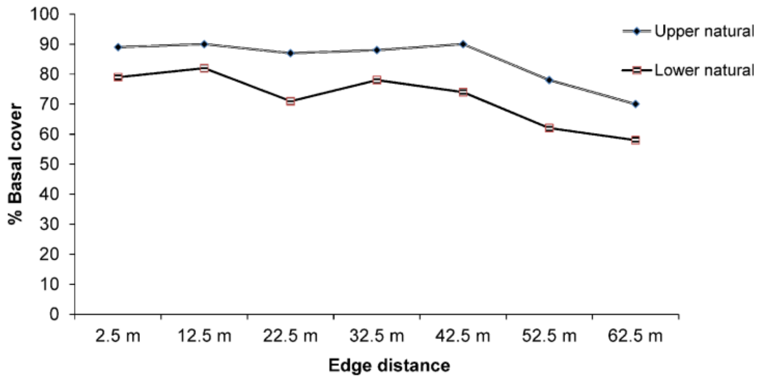

***Fig. 1**: Relationship between plant basal cover and edge distance for upper and lower natural glades*

Forest edge and interior indicator plants

Twelve plant species in the three glade types were identified as indicators of forest edge and four species for the forest interior as listed in Table 4. These were four species of forbs, two species of shrubs and trees for upper natural glades. One tree species was an indicator species in lower natural glades, while two trees and one shrub species were indicator for man-made glades. In the forest interior of the upper and lower natural glades, four species were identified as indicator plants and none was found in man-made glades as there was no forest interior. In upper natural glades, the indicator plants species were a shrub, forbs and a tree, while in lower natural glades only one was identified tree species (Table 4). *Bersama abyssinica* and *Selaginella kraussiana* appeared in both forest edge and interior.

Table 4: Indicator plants in the forest edge and forest interior of the three glade types

Habitat	Glade type	Plant species	Growth form	Indicator value	Habitat condition
Forest edge	Upper natural	*S. kraussiana*	Forbs	80.0[c]	Damp, shaded areas
		P. elegans	Forbs	79.2[b]	Shallow soils
		C. coeruleum	Forbs	69.2[b]	Disturbed (Overgrazed grassland)
		B. abyssinica	Tree	64.7[c]	Shallow, waterlogged soils
		A.bugoiense	Forbs	60.9[b]	Humid, shady places
		N. congesta	Tree	60.0[b]	Forest edge
		C. abyssinica	Shrub	54.7[a]	Forest remnants,
		C. edulis	Shrub	54.7	Forest edge
	Lower natural	*D. abyssinica*	Tree	58.7[a]	Dark soil with much volcanic ash or shallow stony soils at shallow depth
	Man-made	*C. macrostachyus*	Tree	89.4[b]	Wetter area on forest margins and roadside
		T. nobilis	Tree	58.5[b]	shallow stony soils at shallow depth
		S. incanum	Shrub	56.2[b]	Disturbed areas, overgrazed areas
Forest interior	Upper natural	*I. nana*	Shrub	70.6[a]	Moist, shaded area, colder climate
		S. kraussiana	Forbs	60.0[a]	Damp, shaded sites
		B. abyssinica	Tree	58.4[a]	Shallow, damp soils
	Lower natural	*O. welwitschii*	Tree	60.0[a]	Evergreen forest in relative low temperature
	Man-made	None	None	None	None

$^{a}p < 0.05$; $^{b}p < 0.01$; $^{c}p < 0.001$

Trees diameter at breast height (DBH) differed significantly between the three glade types ($F_{(2,189)} = 3.06$, $p < 0.05$). Upper natural glades had the highest mean DBH with 15.5 cm, followed by 10.7 cm and 8.6 cm in lower natural and man-made glades, respectively.

DISCUSSION

Upper natural glades – forest edges and interiors

The mean altitude of the upper natural glades studied was 2, 059 m.a.s.l, which was 405 m and 485 m than the mean altitudes of lower natural and man-made glades, respectively. In general, higher elevation and more mountainous topography results in higher rainfall, lower temperatures, stronger winds and more rocky, shallower soils into glades (Pratt and Gwynne 1977; Vesey-Fitzgerald, 1974; Kashenge, 1986; Blundell, 1987; Haila, 1999). This is supported by the findings that all but one of the indicator plants grows in damp, shaded and colder habitats, as well in shallow soils (Table 4). At the forest edge of upper natural glades, two indicator tree species *Nuxia congesta* and *Bersama abyssinica* were found as reported by (Blundell, 1987) to grow on shallow, damp soils at forest edges and interiors respectively

The forest of upper natural glades had the highest total stem density at an average of 36, 800 stems per hectare, as compared to 27, 700 stems per hectare in the forest of lower natural glades. In addition, had the largest DBH (15.5 cm), higher than 10.7 recorded at lower natural glades and lowest in man-made (8.3 cm) . These findings suggest that the higher rainfall allowed a denser stand of plants and larger growth in tree diameter, althoughthe upper natural glades also harboured the lowest diversity and number of unique plant species (Fahring, 2003). High altitude influences plant diversity and thus, inherently limit species richness and may account for these findings (Hansen and Rotella, 1999). Surprisingly, the upper natural glades were also the forest type in which the plants were the most heterogeneous within glade type, with nine indicator plants found at the forest interior and edge, compared to two in the lower natural and three in the man-made glades. This apparent incongruity may be explained by the greater number of individual plant per species at these high altitude glades.

Along the forest edge (i.e. 2.5 m), there was on average, only a single species of shrub found, but shrub species richness increased to between four and five species with increasing distance into the forest (i.e. 12.5 m). Two indicator shrubs found at the edge were *Clutia abyssinica* or *Carrisa edulis,* and both grow in disturbed areas along the forest edges (Hansen and Rotella 1999; Royal et al. 2010). Ungulates browsing along the forest edge exert a high browsing pressure disturbing forest edges that only these two unpalatable species can tolerate. Both C. *edulis* and *C. abyssinica* are because have sticky milky sap and *C. abyssinica* has spines that may deter ungulates from browsing them (Royal *et al*.2010).

In the upper natural glades, edge effects were prevalent at 42.5 – 52.5 m into the forest. This is because the forest canopy is not high in these forests, and thus, the relatively colder wind and rain penetrate a considerable distance from the edge (i.e. horizontal distance) into the forest. The percentage basal cover and plant species richness also decreased with distance into the forest and the forest was uniform in composition and less influenced by the edge effects. The total abundance of shrubs and basal cover of dwarf shrubs probably caused the observed change at 43–53 m into the forest. Shrubs and dwarf-shrubs thrive on the changing microclimate caused by the interplay of wind, temperature and moisture (Murcia 1995). The basal cover of forbs (59%) was higher in upper natural glades than the other glade types. The four-indicator forbs, *Selaginella kraussiana, Plectranthus elegans, Cynoglossum coeruleum, Asplenium bugoiense,* grow in humid, damp shaded areas and shallow soils (Blundell 1986). *S. kraussiana* was the only plant found in both the forest interior and edge; this is probably due to its ability to compete for both light and shade resources (Spies and Turner 1999).

Lower natural glades – forest edges and interiors

The lower natural glades were located at a mean altitude of 1 654 m.a.s.l., lower than upper natural glades. This glade type had the most homogenous plant species composition, and this is typical of vegetation found at lower topographies (Haila, 1999). The indicator trees in the forest edge of lower natural glades were *Diospyros abyssinica and Olea welwitschii* that grow in dark soil of volcanic ash and in shallow soils (Kashenge, 1986; Van Der Watt and Van Rooyen 1995). The presence of volcanic ash and shallow soils indicate young, immature soils that lack the vertical development of soil horizons.

The forest of lower natural glades had a lower mean total stem density of 27 700 stems per hectare than upper natural glades 36 800 stems per hectare and highest number of unique species (35) compared to (16) for upper natural glades. In addition, a smaller mean tree DBH was observed in the forest edge of lower natural glades (10.7 cm) as compared to upper natural glades (15.5 cm). The difference in tree DBH can be attributed to difference in altitude, topography and soils between the two glade types (Haila 1999). As tree diameter determines the age of individual trees (Spies and Turner1999). Lower natural glades probably harboured younger trees than upper natural glades based on their small DBH

For the lower natural glades, edge effects were detectable at between 12.5 and 22.5 m into the forest. Because the intensity of the wind is lower at lower altitude, the wind probably does not penetrate as deep into the forest as compared to the upper natural glades. The total abundance and basal cover of shrubs and dwarf shrubs were again the growth forms that probably caused this change into the forest due to their characteristics of multi-stemmed and branching at or near ground level. This may also be due to a different microclimate at the edge of lower natural glades that influences plant species composition along the forest edge (Fahring 2003; Harper et al. 2005). The result is a forest that is uniform in species composition and less affected by the edge effects.

Man-made glades – forest edges and interiors

The mean altitude of the man-made glades (mean 15 734 m.a.s.l) was lowest of the three glade types. The lower elevation and warmer temperatures was associated with the presence of two-indicator trees species, the *Croton macrostanchyus* that grows in damp soils in the forests edge, and *Teclea nobilis* that grows on the edge of lower montane forest (Blundell, 1987). In contrast to the natural glades, edge effects were not observed in the forest edge of man-made glades. This was due to management practice of clearing a total of two meters of trees and shrubs at the forest glade interface once a year. The forest edge of man-made glades has been cleared at Mount meru Game Reserve for the past 36 years. This has caused the forest-glade edge to shift toward the forest interior. This shifting of the actual forest edge may have been mirrored by a similar change in the forest interior, with the result, that edge effect could establish and were thus not recorded. The clearing of shrubs and trees results in the development of dense vegetation as regenerating trees and shrubs fill in open space in the clearing (Harper *et al.* 2005). Formation of dense vegetation reduces wind energy penetration into the forest (Harper et al. 2005; Laurence *et al*. 2001). Hence, the edge effect of man-made glades is less than that of natural glades.

The forest around man-made glades had the lowest total stem density in the forest at an average of 11 914 stems per hectare, compared to lower natural glades. This was coupled with smallest mean tree DBH (8.6 cm). The small tree DBH at the forest edge of man-made glades is probably management-related, in that, big trees are cleared and only small trees are left behind. This is an indication of forest succession, where changes in structure and composition tend to be rapid immediately after clearing (Spies and Turner 1999). Early succession is also, accompanied by younger individuals at the forest edge, which is an indication of a young forest succession (Van Amhild, 2005).

CONCLUSION

In conclusion, the plant species composition (as analysed by the MRPP) in the forest of man-made, upper and lower natural glades differed significantly between habitats, as well as the plant species composition of forest edges. Since the plant species found in the forest and at the edge of man-made glades were different from the others, the conservation value of these plants was judged to be high. However, the forest interior and edge found bordering man-made glades are in fact man-modified forest interiors, so the origin of plants found near this glade type can in effect be found all over the forest. This supposition obviously lowers the conservation value of these plants.

Overall, only the species richness of forest edge plants increased the conservation value of man-made glades, whereas the lack of edge effects, and the low total abundance and species richness of forest interior plants, and the low number of unique plants lowered the conservation value. Therefore, it can be judged that conservation value of forest plants of man-made glades are too low to be conserved, although they have conservation value because they are a resource for wildlife.

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IMPACT OF CLIMATE CHANGE AND LAND USE ON LOCAL BUTTERFLY POLLINATORS: A CASE OF DAR ES SALAAM, TANZANIA

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ABSTRACT

Butterflies were used as indicator species because of their high sensitivity in ecosystems alteration. It is expected that changes in land use and climate will greatly change the butterfly fauna in Dar es Salaam. Assessment of the abundance and presence of butterfly pollinators in Dar es Salaam was carried out by comparing recent data (2008 to 2009) with previous data (1977 to 1978) from the same sites. The total number of species and individuals in both set of data were identified by classifying the butterflies to species level using identification guide. The expected changes on abundance of butterfly pollinators in previous and recent studies were documented using ranking method or t-test. Using the same data, the effects of climate change and land use on abundance of butterflies were identified using Fisher test. The values of species in past and recent data were compared using correlation analysis.

Findings show that there are 54 species of butterflies identified; 32 species from the previous data and 22 species from recent data. Abundance changes of butterfly pollinators between the two sets of data were significantly correlated. There is decrease of species in recent data as compared to previous data. However, the species show great abundance in previous data as compared to recent data. This change is consistent with previous studies that changes in abundance of butterfly pollinators can be caused by changes in climate and land use together with interactive effect of environmental changes. The study recommends more researches to be done on the impact of climate change and land use on pollinator species to trace trend of butterflies in Tanzania. Afforestation of the area can be used as remedial measures to attract back the migrated species.

Keywords: Climate change; Land use; butterfly, indicator

INTRODUCTION

Climate change

Climate change has impacted the global distribution and abundance of organisms, leading to recently increased incidence of extinctions. Global climate change threatens the survival of ecological communities and individual species, including humans (IPCC 2001, McCarty 2001). The projected rapid rise in temperature and destruction of habitats from land use change could easily disrupt the connectedness among species, transforming existing communities, and showing variable movements of species through ecosystems, which could lead to numerous localized extinctions. If some plant species are not able to respond to climate change, there could be increased vulnerability of ecosystems to natural and anthropogenic disturbances, resulting in species diversity reductions (Malcolm *et al.,* 2002). Historically, climate change has resulted in dramatic shifts in the geographical distributions of species and ecosystems and current rates of migration of species will have to be much higher than rates during post-glacial periods in order for species to adapt (Malcolm *et al.,* 2002). Vast forest disappearance due to climate change-induced die-back and land use change which substantially affect species composition and global geochemical cycling, particularly the carbon cycle (Malcolm *et al.,* 2002).

Approximately 15% to 37% of animal and plant species are predicted to be exposed to the risk of extinction after 2050 (Thomas *et al.,* 2004). Insects are highly dependent on temperature for their poikilothermic properties and rapidly adapt and/or migrate following changing thermal conditions due to their high mobility (Kiritani and Yukawa 2010). They have ability to colonize every corner of the planet, however, these creatures have been facing several threats both from human induced and natural causes. While urban biota could also be biological indicators of the health environment yet an ever growing population and the demands of human needs puts pressure on the local flora and fauna. Dar es Salaam city is a major administrative, commercial, industrial and transportation centre in Tanzania and one of fastest growing cities in sub-Sahara Africa. Resource degradation due to the impact of industrialisation, expansion of both planned and unplanned settlements (Burra,1997) causing the encroachment of ecosystems, propagation of alien plant species, overexploitation of natural resources and habitat loss has altered the composure of the urban ecosystem drastically. The explosion of the city population goes together with the fast changes in the city landscapes which is causing dramatic environmental changes. Data on this dramatic changes is crucial to trace the trend of species survival.

Among the key roles of museum specimens is to represent an invaluable database on the geographical distribution, historical and current range and on the phenology of species. The specimens also serve as the database on the biodiversity of particular geographical regions. By examining museum specimens, researchers have been documenting the effects of climate change on a variety of organisms and furnished a glimpse of future impacts. Using these data changes in the distribution of species through time (including their extinction) and changes in the biology of particular species in response to climate changes can be established. Museum collections have also shown that the effects of global warming have altered the biology of some species. This has increased value of museum data towards conservation of biodiversity. Parmesan (1996) compared data of butterfly (*Euphydryas editha*) at 115 sites in North America with historical records from museum collections. Findings showed that southern populations (in Mexico) were four times more likely than northern populations (in Canada) to have gone extinct, resulting in a significant northward range shift. Similarly, when the histories of 35 European butterfly species were examined, 63 percent had ranges that had shifted to the north, whereas only 3 percent had advanced to the south (Parmesan *et. al.,*1999).

Butterflies are highly appreciated by the public because of their beautiful appearance and daytime activities, which can be easily observed and have economic, social and ecological importance that calls upon their proper conservation. Because of their importance in the functioning ecosystems they provide pollination to specific species of plants; food for many animals; they act as a platform for science education; and they are worth millions of dollars to economies around the world. Ehrhart and Blomley (2006) noted that butterfly farming in Tanzania has raised gross family income (TZS 518,386), and the local community supported the conservation of the ANR as the result the conflict between the local community and the reserve conservationists were eliminated. Study done by Chris (2012) noted that butterflies are good predictor of other species richness e.g. birds, lichens and plants in Portugal, Spain, France but not a good indicator of soil biodiversity.

The increase of human populations in city centers and urban sprawl has eliminated or severely restricted green space and threatens habitats. Butterflies face a wide range of threats including habitat loss, climate change, disease, pesticides, and invasive plants—all of which are leading to declines in many species worldwide. The survival of butterflies is affected by various factors of urbanization (Dennis & Hardy 2001; Wood & Pullin, 2002). Urban development, habitat loss, and fragmentation have a negative impact on butterfly species distributions, species richness, and Shannon diversity (Blair & Launer, 1997; Di Mauro, *et. al*., 2007). Effectively, habitat changes that are significant enough to critically alter the niche requirements of a butterfly species constitute a loss of habitat. Habitat changes result in an absence of conditions, resources and biological interactions that are required by individuals of a species for their survival (Begon *et. al.,* 2006). At present, the most significant causes of butterfly habitat loss in Dar es Salaam City are: invasive alien vegetation, urban agricultural activities, urbanisation, building and road construction. Urbanisation has recently been at the centre of a few high-profile butterfly conservation situations. The construction of buildings and roads or the ploughing of a field could lead to the extinction of a rare species confined to a single locality.

Most butterflies rapidly respond to land use and climate change due to their high fecundity and short generation time (Feest *et al.,* 2011). Butterflies have been most frequently studied to determine the impacts of climate change (Parmesan *et al.,* 1999) and are strongly associated with vegetation structure and composition (Lomov *et al.,* 2006) due to their popularity and well-known taxonomy, distribution, and ecology (Parmesan *et al.,* 1999). Butterflies (Lepidoptera) are very sensitive to disturbances, which makes habitat fragmentation, degradation and destruction of natural landscapes, the most important causes for declines in butterfly assemblages (Uehara-Prado *et al.,* 2007). Butterflies are frequently used as indicator species for biodiversity response to anthropogenic and environmental changes (Notø, 2014). Their sensitivity to environmental changes, their responsiveness to biodiversity patterns of other taxa, the comparatively well-known life history of butterflies (Cleary, 2004), and the fact that they are relatively easy to observe, catch and identify, all together makes this order convenient for using in monitoring forest disturbances (Cleary, 2004).

Study by Warren *et al.,* (2001) shows that butterfly species respond differently to vegetation change suggesting that climate change and land use interact to influence organisms. Likewise, land use caused by human activities may hinder the abundance of butterflies. Thomas (2001) put out that as habitats are greatly fragmented, butterflies could not migrate between fragmented habitats. Anthropogenic disturbances such as construction, cultivation, and change of land use also significantly influenced butterfly assemblages (Balmer and Erhardt, 2000; Franzén and Ranius, 2004; Honda and Kato, 2005).

Previous studies by Ngongolo *et al*., (2013b; 2014b) on butterflies in Dar Es Salaam have been reported on butterflies abundance and diversity as a measures of health biodiversity in a restored land. Also, findings by Lomov *et al*., (2006) show a considerable increase in butterfly species richness in restored areas compared to the disturbed areas in Australia. So far in Tanzania, however, impact of climate change and land use on local butterflies using museum data has not been studied due to the fact that most climate change and land use projects have been focused in large ecosystems. A number of studies have been done on butterfly farming Morgan-Brown (2003) in the East Usambara Mountains; effect of anthropogenic disturbances on fruit-feeding butterflies (Nymphalidae) in Amani Nature Reserve (Notø, 2014). Though butterflies are some of the most recognizable and well-loved insects in the world, we still know relatively little about their status. However, most studies on impacts of climate changes on butterflies have concentrated on distributional changes at regional or global scales, whereas local changes at community levels are very rarely reported. It is important to conduct research on impact of climate change and land use in urban areas because many, almost urban biodiversity have been ignored. Because of their popular importance in research, and education materials evidence of people and their environment, application of museum collections to the environment should be known. Primarily, collections document the presence of particular species at a particular place and time. This study therefore assesses the abundance and presence of butterfly species in Dar es Salaam City using two data sets from the museum collections.

MATERIAL AND METHODS

Study areas

Dar es Salaam city is located in the eastern part of the Tanzanian mainland at 6.8º1′S latitude and 39º28′ E longitude (Dongus, 2000). The city is divided into three ecological zones, namely the upland zone comprising hilly areas to the west and north of the city, the middle plateau and the lowlands, which include Msimbazi Valley, Jangwani, Mtoni, Africana and Ununio. Temperature trends over the past four decades show significant increase and is projected to increase (TMA, 2010). The annual average temperature has increased approximately 1.5ºC since 1912 which is twice the global average. Mean temperature increases approximately 0.6ºC in coastal regions alone whereas in inland about 1.5ºC to 2.5ºC (TMA, 2010). By 2100 mean annual temperature for Tanzania is expected to increase by 1.7ºC cover the northern coast including areas around Dar Es Salaam (Matari *et al.,* 2008). Both rainfall amount and intensity are variable of concern from the view of flooding. Intensity has been increasing in last 15 years and has been well above the 38 years recorded history. This trend is expected to continue with climate change (TMA, 2010).

Sampling design

The majority of the previous data were collected from 1977 to 1978 explain the nature of these data. The recent data were from 2008 to 2009 characterised by newly occurred and unchanged individuals. The butterfly species were grouped with their abundance trends from the two data sets regardless number obtained from three ecological zones; the upland zone comprising hilly areas to the west and north of the city, the middle plateau which include Msimbazi Valley, Jangwani, and the lowlands, which include Mtoni, Africana and Ununio. Though the number of individuals was recorded in both data sets, the survey methods used were different.

Data analysis

The rank (%) of a species was then estimated using the t-test. The difference in the rank (%) of abundance between the previous and recent data was then used to represent the abundance change of each species. To identify the effects of global warming on abundance, the number of previous species which increased (i.e., positive value of abundance change) or decreased (i.e., negative value) was compared with that of recent species using Fisher exact test (Zar, 1999). Comparison in the value of species in previous and recent data was done using correlation analysis. In addition to evaluating the change in abundance, qualitative data regarding the presence or absence of each species was also analyzed. The butterfly species that were present in the previous survey but absent in the recent survey were classified as 'local extinct species,' while butterfly species that were absent in the previous survey but present in the recent survey were classified as 'newly occurred species.' Species that occurred in both the previous and recent surveys were classified as 'unchanged species.'

RESULTS

Families and species of butterfly that occurred in previous data and recent data

Findings show that there are 54 species of butterflies identified; 32 species from the previous data and 22 species from recent data. Five families of butterflies identified were grouped as follows: abundant (2 families), common (3 families), rare (2 families). The abundant butterfly group and the common butterfly group were well represented in both data sets. In this group, the three dominant families were Nymphalidae, Pieridae and Papilionidae (Table 1). The t -test reveals extremely significant variation on abundance of butterfly number in two sets of data (t-test =3.938413, p=0.000211at $p<0.05$) (Fig. 1). The test also reveals extremely significant variation on abundance of butterfly species in all butterfly groups from both data sets as follows: abundant butterfly groups (t-test = 3.341275, p=0.002376 at $p<0.05$); common butterfly group (t-test = 4.259468, p=0.000121 at $p<0.05$) and rare butterfly group (t-test = 4.743416, p=0.000124 at $p<0.05$) (Fig. 3). Indeed, more individuals were collected in the previous data (341 individuals, on average of 68 individuals /family) than in the recent data (49 individuals, on average 10 individuals/family).

Table 1: Families and species of butterfly in previous data and recent data (Groups of Butterflies (GoB): Abundant Butterfly Group-ABG, Common Butterfly Group-CBG & Rare Butterfly Group-RBG; Present or Absent (A/P) of butterfly species: Local Extinct Species-LES, Newly Occurred Species-NOS, & Unchanged Species- US)

Previous Data Set 1977/8				Recent Data Set 2008/9			
Family	**Species**	**No. per species**	**A/P**	**Species**	**No per species**	**A/P**	**GoB**
Nymphalidae	*Charaxescithaeron*	3	US	*Charaxes zoolina*	1	US	ABG;CBG
	Précis sp.	31	US	*Charaxes ethalia*	1	US	
	Charaxescandriope	13	US	*Hypolimnus missipus*	1	US	
	Hypolimnasdeceptor	3	US	*Euphaedraneophron*	4	US	
	Hypolimnasdubiamima	1	US	*Acraea sp.*	2	US	
	Charaxesvioletta	4	US	*Bicyclus*	3	NO	

Previous Data Set 1977/8				Recent Data Set 2008/9			
Family	**Species**	**No. per species**	**A/P**	**Species**	**No per species**	**A/P**	**GoB**
				campinus		S	
	Acraeasatis	1	US	*Bybliailythia*	1	NOS	
	Salamis sp.	25	LES	*Neptis sp.*	1	NOS	
	Danausdorippus	26	LES	*Précis hierta*	2	NOS	
	Acraethesprio	24	US	*Précis oenone*	2	NOS	
	Charaxes castor	5	US	*Danauschrysi sp.*	2	NOS	
	Amaurisochlea	1	LES				
	Mycalesisxeneas	49	LES				
	Bybliailythia	14	US				
	Issoriahanningtoni	6	LES				
Pieridae	*Coliaselecto*	10	LES	*Colitis antevippe*	5	NOS	CBG
	Mylothrisagathina	18	LES	*Belenoiscreona*	3	NOS	
				Euremahecabe	2	NOS	
				Euremabrigitta	4	NOS	
				Colitis danae	5	NOS	
				Leptosiaalcesta	1	NOS	
				Catopsiliafrorella	1	NOS	
Papilionidae	Papiliodardanus	45	US	*Papiliodemodocus*	2	NOS	CBG
	Papilio fuelleborni	15	LES	*Papiliodardanus*	1	US	
	Papilio hesperus	20	LES	*Papiliopolystratus*	4	NOS	
	Papilio nobilis	8	LES				

Previous Data Set 1977/8				Recent Data Set 2008/9			
Family	**Species**	**No. per species**	**A/P**	**Species**	**No per species**	**A/P**	**GoB**
Hesperiidae	*Spialia dromus*	4	LES	*Borboborbonica*	1	NOS	RBG
	Tagia lesflesus	2	LES				
	Coeliades forestan	1	LES				
	Zino mazeno	1	LES				
	Acadabiseriatus	1	LES				
Lycaenidae	*Hypolycaena philippus*	3	LES				RBG
	Hypolycaenaceres	3	LES				
	Myrina ficcechila	1	LES				
	Freyeri atrochilus	1	LES				
	Pentila mombasae	1	LES				
	Axiocerce samunga	1	LES				
TOTAL	**32**	**341**		**22**	**49**		

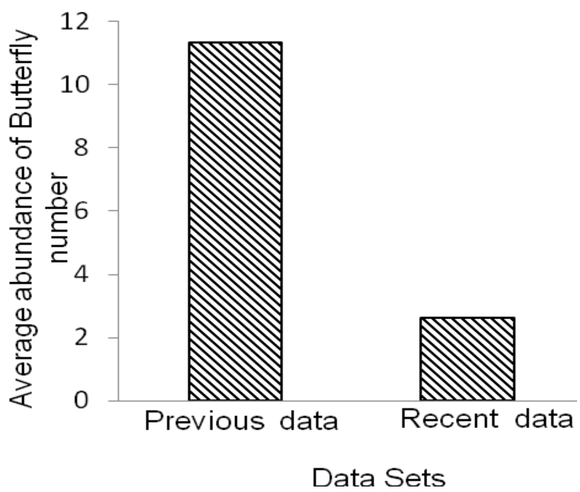

Fig. 1: *Average abundance of butterfly number in previous and recent datasets, ***$p<0.05$ E.S extremely significant*

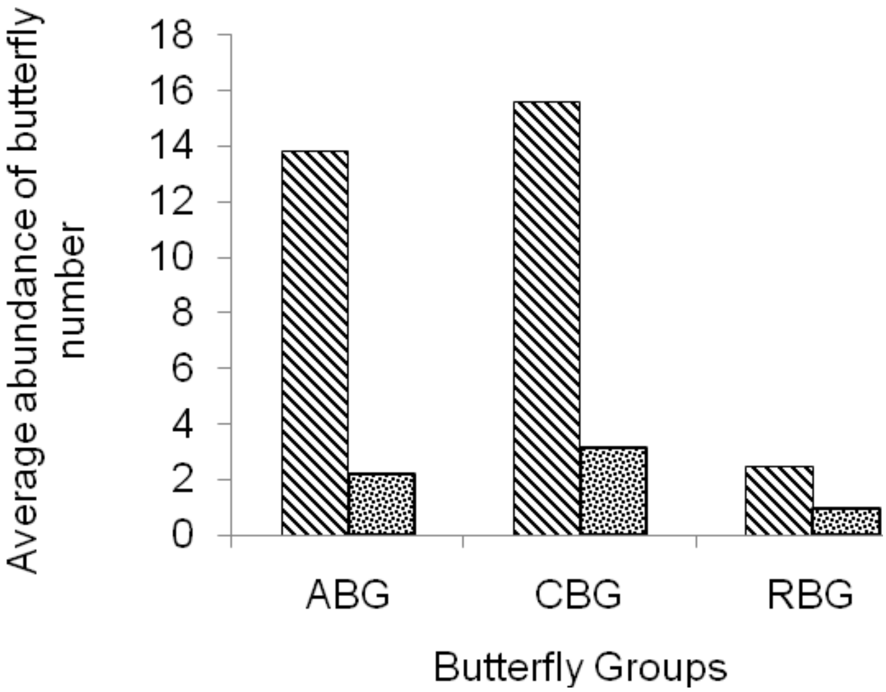

Fig. 2: *Average abundance of butterfly number in the three butterfly groups from the two data sets: abundant butterfly group –ABG, common butterfly group-CBG and rare butterfly group-RBG ***p<0.05 extremely significant.*

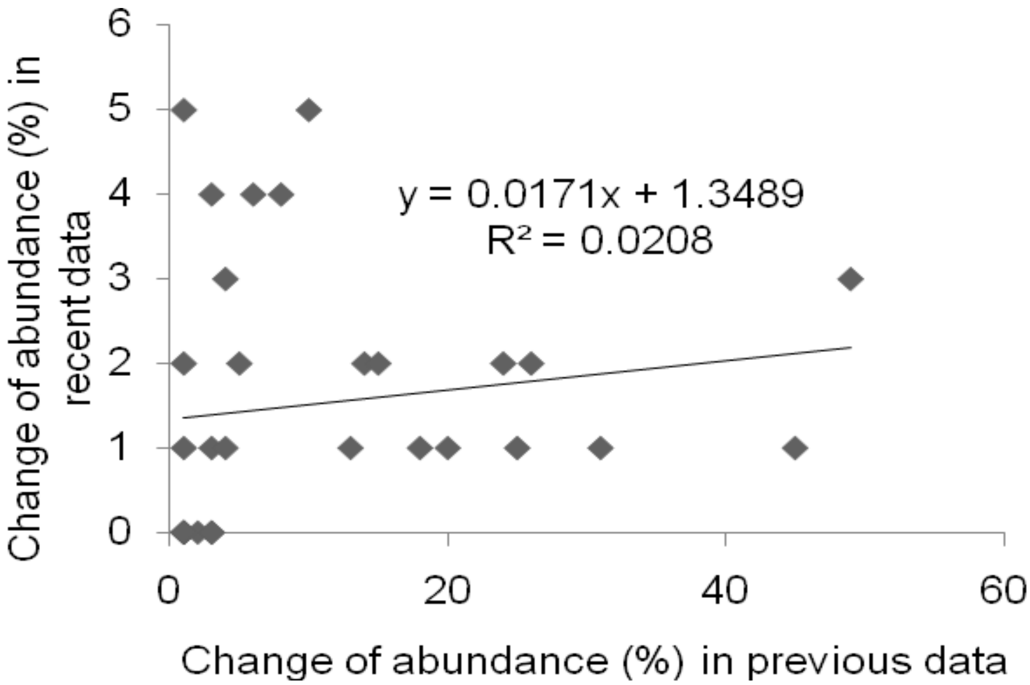

Fig. 3: *Abundance change of butterfly number in the two data sets; values for the previous data are positively correlated with those of the recent data (weak) (r=0.1442, p=0.431052), and the line represents the values of the two data sets.*

Effect of climate change and land use on butterfly abundance

Fisher's test was used to identify the impact of climate change and land use on butterfly abundance. Numbers of butterflies in abundant and rare butterfly groups were used to calculate the p –value. The Fisher's test shows P-value = 1 therefore the result was not significant ($p<0.05$). Though, there is no enough evidence to conclude that the probability effects of climate change and land use is higher at present data set than in the previous data set it is apparently that the number of butterflies keeps on decreasing as time goes. This can be evidenced by sampling size from the previous and recent collection.

Abundance change of butterfly number in previous data and recent data

Correlation analysis using numbers of butterfly species was performed to compare the values in the species between previous and present data sets. Changes in the abundance of butterfly species that occurred at both data sets were significantly correlated ($r =0.1442$, $p=0.431052$ not significant at $p<0.05$ Fig. 2). The positive correlation strongly suggested that the changes observed in the present study may be general trends of populations in the study area, which were caused by exogenous environmental factors rather than stochastic events.

DISCUSSION

Similar trends of abundance change for 54 species of butterflies between previous and recent data sets demonstrated that long-term change in abundance of butterfly species may have occurred between 1980s to 2000s. This change was probably not caused by stochastic yearly variation, but the previous study years and recent studies differed in terms of increased human pressure on land. The most increased species were mostly in family Nymphalidae, but the most decreased species were mostly in families Hesperiidae and Lycaenidae. This finding strongly suggests that the local change of abundance might be driven by migration of butterfly species to safer and more favourable places. It is an assumption that during migration, the abundance of butterfly species in the previous records was on increase whereas that of recent species was on decrease. The change of abundance would also change the chance of collection (previous survey) or observation (present survey) of species, which was represented as the frequency change of newly occurred or not observed /locally extinct species in the present study.

Regarding the 54 butterfly species observed at both data sets, families Lycaenidae and Hesperiidae showed to decline more than other families. Families Nymphalidae and Papilionidae were abundant in number of individuals within the species in the previous data and moderately abundant in the recent data. Species in these were commonly found in the upland zone comprising hilly areas to the west and north of the city and the middle plateau prior to the early 1980s. It is now found mostly in few undisturbed areas such as peri-urban areas and botanical gardens. These findings indicate that a shift of species to the lowland areas is likely to happen due to rapid expansion of human activities in the area.

The qualitative data (i.e., frequency of local extinct species, unchanged species and newly occurred species) in the recent study support the expected changes of butterfly species based on climate change and land use which is comparable with the abundance change. The effect of land use and the interactive effect of climate change were found in the species change as well as in the abundance change. The change of butterfly species occurred in parallel with the change of butterfly abundance in response to environmental changes. In the newly occurred species, most species are from the recent data set, but all other species are from previous data set. This finding strongly indicates that the recent species might have been affected by the land use and climate change but the previous data set species were relatively less disturbed, thus, their presence and abundance remained constant.

The effect of climate change and land use lack enough evidence to conclude the difference between the two data sets. However, the study by Begon *et al.(*2006) shows that habitat changes result in an absence of conditions, resources and biological interactions that are required by individuals of a species for their survival. Resources and biological interactions as explained by Kroon (1999) include the availability of larval host plants or nectar and other food sources of adult butterflies.

Though this can be attributed to migration factor, the number of local extinct species was highest among the families, whereas the number of unchanged species was lowest among the families. These findings indicate that the populations of the recent data species were more unstable and/or more mobile than those of the previous data species, and that species change due to the land use was different between two data sets. Local extinction of previous-abundant species was observed for twenty two species from all families. Loss of habitats as result of construction activities may also be related to the rapid decline of the species in addition to global warming. The combined effects of habitat loss and temperature rise may significantly deteriorate the adaptability of these species in some ecological zones.

The newly occurred species were frequently observed and collected during the recent study period despite a decline in habitat since the early 1990s. Such a new introduction may be possible because these species might have seasonal migration at the time of data collection or may recently been able to adapt with changes in climate and ability of using different plant species as sources of nectar, food and larval hosts. The change in land use in the city caused change in abundance of butterfly communities, in which species decreased as the rate human activities increased. It was assumed that new occurrence and local extinction in recent data may be different between species due to climate change, and also differ from previous data due to land use change.

CONCLUSIONS

The recent study shows that simple binary data (presence/absence) obtained from museum collections can be useful in the assessment of impacts of climate change and land use on local butterfly fauna. Such data may be more easily obtained at low costs and can be used to identify impacts of climate change using nonparametric statistics, as evidenced in the recent study. Such qualitative data may also be much more available than abundance data in many regions, because most data concerning butterfly fauna in the world are binary rather than quantitative.

Clearly there is some limitations of the research study. In the face of climate change impacts on urban areas, this research approach and methodology could easily be applied and modified to test the ecological benefit of afforestation on the area. Due to the seasonal variation of some tropical butterflies it is also recommended that an extended study with data for at least three wet and dry season be undertaken to ascertain if species in the study area were truly seasonal. A more comprehensive study to consider butterfly groups in relation to their larval host plants, food preference and presence of nectar is necessary.

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IMPACTS OF THE TANZANIA-ZAMBIA TARMAC ROAD ON WILDLIFE ROAD KILLS AND LITTERING IN MIKUMI NATIONAL PARK

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ABSTRACT

This study was conducted on a stretch of 50km tarmac road traversing the Mikumi National Park in order to establish the magnitude, spatial and temporal trend of road kills, determine vehicle speeds and time spent to pass through the park and wastes in the park. A cross sectional study, previous records and questionnaire were used to collect the required data as well as to gather opinions from communities. Results showed 29 road kills (mostly mammals) per month with an average of about one road kill per day. The proportion of animals killed per age was 45.5% adults, 3% juveniles and 51.5% of animals killed could not be assigned any age as they were completely crushed. There was no significant difference between sex of animals killed (P= 0.1859). Position of animals killed on the road showed no significance differences among right, centre and left (P =0.05875). An average of 1,758 vehicles passed through the park per day from either direction where the majorities were lorry (1,002) of which 631 entered through Kikwaraza gate and 371 through Doma gate. The average speed of vehicles that passed through the park during the day were 90 km/h for buses, 63.34 km/h for lorries, 77.67 km/h for min buses, 82.4 km/h for medium sized and 83.55km/h for Saloon categories of vehicles. Except for few lorries, most vehicles speed were over and above the speed limit of recommended by the park during day time of 70km/h. Most of the recorded vehicles spent little average time to cross the park (0.32-0.59 hours), which was contrary to the optimal time to cross the road section for 0.63 hours. Results showed that on average a total of 138.3 kg of solid wastes, mainly tyres and tubes (70.36%), glasses and mirrors (10.4%) and plastic bottles (5%) by weight were littered per day in the park (plastic wastes ranked number one in terms of volume). It is concluded that the Tanzania-Zambia road has significant negative impact to Mikumi National Park, in terms of wildlife road kills, wastes, costs of waste and road kills collection and incineration, and overall biodiversity and visitor satisfaction at large. In order to reduce these impacts, use of an alternative road via Kilosa, awareness education to road users, increased road patrol, increased penalties for offenses are the main recommendations.

Key word: Tarmac road, National Park, Road-kill, Littering

INTRODUCTION

Worldwide, highways across wildlife refuges are an intrusion and affect the wildlife and its habitats adversely. The effects may range from habitat loss and fragmentation (Burnett 1992; Richardson *et al.*, 1997; Carr & Fahrig 2001) to affecting the wild animal distribution pattern (Newmark *et al.*, 1996), movement (Desai & Baskaran 1998), breeding density (Reijnen *et al.*, 1995), heterozygosity, genetic polymorphism (Reh & Seitz 1990) and directly by mortality through collisions with vehicles (Oldham & Swan 1991; Foster & Humphrey 1995; Das *et al.* 2007; Row *et al,*. 2007; Shwiff *et al.* 2007; Seshadri *et al.*, 2009).

Road kills is a common phenomenon in many wildlife populations worldwide (Ashley and Robinson 1996; Mysterud, 2004; Rolandsen *et al.,* 2011). Several studies have determined the extent and distributions of road killed animals in protected areas (Drews 1995; Rolandsen *et al.* 2011). These findings have concluded that road kills is among factors contributing to increased wildlife species loss or extinction (Dussault *et al.* 2006; Selvan *et al.,* 2012). The taxa mostly affected ranges from mammals (Newmark 1992; Drews 1995; Newmark *et al.* 1996; Richardson *et al.*, 1997), birds (Reijnen *et al.*, 1995; Drews 1995), reptiles (Rosen & Lowe 1994; Drews 1995; Gokula 1997; Das *et al.* 2007) and amphibians (Reh & Seitz 1990; Fahrig *et al.*, 1995; Seshadri *et al.*, 2009).

Existence of public roads across protected areas has positively influenced road kills due to high traffic and speeding (Drews 1995; Selvan *et al.*, 2012). For instance road users have been observed to be involved in road kills due to failure of adherence to safety driving practices and lack of awareness on park regulations and warning signs (Selvan *et al.*, 2012). Furthermore, previous studies have indicated that there is a direct link between existence of green pastures on road verges and presence of herbivores (Oxley *et al.,* 1974; Forman and Alexander 1998; Fahrig and Rytwinski 2009). Presences of grazing herbivore species and carcasses along the roads in protected areas may attract variety of carnivore species and birds of prey subjecting them to high risk of road kills.

Tanzania has reserved 30% of its land to protected areas with highest wildlife populations in Africa consisting of several world heritage sites and biosphere reserves (Sinclair 1995; Hilborn *et al.,* 2006). In Tanzania, some of the conserved areas including Mikumi National Park are traversed by both public transport and tourist roads. Mikumi National Park is located in the Morogoro region within three districts: Kilosa, Mvomero and Morogoro. The park was initially gazetted in 1964 covering an area of 1,070 km^2. The boundaries were extended in 1975 to its current size of 3,230 km^2. The northern half of the park is traversed by a major trans-national highway linking Dar es Salaam with Malawi and Zambia over a stretch of 43.5km. The road was initially paved in 1972, and resurfaced in 1977 -1978 later rehabilitated to tarmac level in 1990-1991.

There are significant management challenges facing the park, which are resulting from the existing tarmac road. The road has been a conservation challenge in the park. Previous study by Drew, 1995, has documented negative impacts of road kills on wild animals including the endangered and threatened animals such as African wild dog (*Lycaon pictus*) and the African Elephant (*Loxodonta africana*) respectively. A number of factors have contributed to the increase in road kills such as ignorance of the park safe drive regulations, poor time management by driver and presence of a tarmac road. In order to design rational mitigation measures for road kills and proper waste disposal; data and information on the relationship between the highway and wildlife is a pre-requisite. This study was conducted to determine the actual impacts of the road to wildlife, underlying cause(s) and spatial-temporal patterns of road kills as well as littering in Mikumi National Park. To attain sustainable wildlife conservation through reduced road kills and proper waste disposal by road users in Mikumi National Park. The main objective was to determine the current impact of road kills to wildlife and evaluate spatial-temporal pattern and impact of littering in Mikumi National Park. The specific objectives of the study were to determine the magnitude and trend of road kills in MINAPA, to estimate the average speed and time spent by vehicles using the road in the park, to determine the spatial-temporal pattern of road kills in MINAPA, to determine the magnitude of littering along the road in the park and lastly to establish stakeholder's perceptions on the impacts of the tarmac road passing through MINAPA to wildlife and control measures.

MATERIALS AND METHOD

Study area

MINAPA is a protected area of approximately 3,230 km^2 located between longitude 37°00' to 37°30'E and latitude 7°00' 7°45' S, in Tanzania. The area is predominantly Miombo and Acacia woodland with species of Acacia trees and also comprises of open grass plains. The area forms the northern portion/section of the Selous ecosystem and is rich in mammalian species such as elephant (*Loxodonta africana),* buffalo (*Syncerus caffer),* wildebeest (*Connochaetes taurinus*), eland (*Tragelaphus oryx),* giraffe (*Giraffa camelopardalis),* zebra (*Equus burchelli),* lion (*Panthera leo),* leopard (*Panthera pardus),* and wild dog (L*ycaon pictus*).

The park experiences two seasons, wet season from December to May and dry from June to November, with mean annual rainfall varying from 650 - 850 mm and peak time during March and April. Average monthly temperature in the park ranges from 22 - 26°C

METHODS

Study design

A cross sectional study design was used to collect data along the stretch of 50 km tarmac road passing through MINAPA. The road transect, was purposively selected to run from Doma to Kikwalaza gates. Semi structured questionnaire was administered to 91 respondents among park stakeholders (park staff, researchers, tourists, tour guides drivers, business dealers) who were randomly selected to acquire opinions on the impacts of the road to wildlife and littering in the park. Secondary data was also collected from the park on longitudinal data for road kills and waste management.

Data collections

The required data on magnitude, vulnerable species and spatial-temporal pattern of road kills involved collection of data on animal species killed, location on the road side, number of animals killed, age, sex, weather and type of vegetations found along the road. In addition presences of scavengers of unrelated species were recorded in a standardized data sheets. Photographs of carcasses were taken to further aid the process of identification. Vehicle speed was determined by the use of speed gun, time taken for vehicles to pass from one gate (entry) to the other gate (exit) during day and night time was recorded by subtracting the entry and exit time by placing two people at each gate for recording entry and exit time in a data sheet. Perception of stakeholders on the impact of the tarmac road through MINAPA on wildlife and littering was collected using a questionnaire of both open and close ended questions. The details of data collection methods were as follows:-

Assessment of wildlife road kills

A vehicle with two observers was driven at an average speed of 35 km/h, from Doma to Kikwalaza gate starting at 0600h morning from April to June, 2014. When a dead animal or sign(s) of road kill was seen, the location of each sampling plot was recorded using Global Positioning System (GPS) Garmin 60 csx. Weather of the day, vegetation type, position of a kill on the road, species name, sex, and age were determined and recorded in a data sheet. Age of animals was determined based on the four established categories: "young", "juvenile", "adult" and "unidentified". Sex of an animal was also categorized into "male" and "female". Wherever, a kill was completely crushed thus, it cannot be identified in terms of age and sex then it was recorded as "unidentified". Photos were also taken for further identification. Presences of carcasses of unrelated animal species were recorded including their numbers and specie names.

Determination of time spent and numbers of vehicles passing through the park

Two observers were allocated at each gate (Doma and Kikwalaza as entry and exit points) to record arrival/exit time of the vehicles passing through the 50 km road stretch from either direction. Doma was used as entry gate when a vehicle entered the park through Doma with Kikwalaza gate being used as an exit gate and vice versa. Upon arrival of any vehicle at each gate (entry or exit), the vehicle registration number, type of vehicle and time of entry or exit were recorded. Types of vehicles passing through the park were classified into five broad categories namely; "Lorry", "Bus", "Mini Bus", "Medium size" and "Saloon". Communication of observers on both gates by use of mobile phones was done to mark the first three vehicles to enter and exit on either side to mark commencement of recording the time of entry and exit of vehicles respectively. The total number of vehicles passing through the park per day was determined by counting all vehicles passing (tallying) during day and night times using two people standing side of the road at the park head quarters junction to the highway, vehicle counting was done in shifts of 6 hours.

Determination of average vehicle speeds

In collaboration with traffic police from Mikumi Police Station, a speed gun was used to obtain the average speed of vehicles passing through the park at different points including road humps, warning signs and areas without warning signs. To eliminate the influences of traffic police to drivers and road users, a civilian/personal vehicle was used, traffic police clothed civilian clothes (non-traffic garments), vehicle speed was recorded inside a car, the civilian car was packed either aside the road as a vehicle with a technical problem. Usually, drivers have a tendency of alerting each other when traffic police are at a certain point of the road to monitor and penalize over-speeding vehicles.

Perception of stakeholders on the impacts of road on wildlife and littering in the park

Information required was collected using a semi-structured questionnaire with both open and close ended questions. The semi-structured questionnaire was administered to 91 stakeholders from Doma, Mikumi town, MINAPA park staff/researchers, drivers on the road, tourists at Lodges, and camp sites to assess knowledge, attitudes and practices related to road kill and littering in the park. Stakeholders for the questionnaire were purposively selected based on the proximity to the road and the park. For each study unit (Mikumi town, Doma and MINAPA) a randomized sampling technique was applied to obtain a sampling unit.

Estimation of the amount of littered materials in the park

Before collecting data on wastes in the park, all wastes along the road through the park were collected on day one. After three days, litter collection was done by walking and collecting all visible refuses/wastes along the 50 km stretch of the tarmac road traversing the Park. This was done by use of casual laborers who were allocated portions of the road, given collection bags and a truck to put collected wastes was driven along the road. Collected wastes were sorted into nine categories namely plastic bottles, tins, tyres and tubes, metals, glasses, papers, plastic bags, clothes and wooden materials. The weight of each waste type were taken and recorded into a data collection sheet. All the litter collected was taken to a designated damping area near Mikumi town for disposal and incineration.

Data analysis

Descriptive statistics in Statistical Package for Social Sciences (SPSS Ver.20) was used to analyze information on magnitude, vulnerable species and opinions of stakeholders on road kills and littering in the park. Excel programme was used to determine the amount of litters on daily basis. Arc View GIS ver. 10 was used to obtain spatial and temporal patterns. A Past Software was used for a Tukey's pairwise comparison test for categorical variables. One way ANOVA test and Shannon Index method for evenness of road kill species were used.

RESULTS

The magnitude and vulnerability of wildlife road kills in the park

Wildlife numbers of road kills

During the study period of April, May and June a total of 56 mammals belonging to 15 species (Table.1); 23 birds belonging to 8 species and 5 unidentified birds (Table 2); 6 reptiles and 1 toad (Table 3) were killed by vehicles along the road through the park. Retrospective data from MINAPA Ecology Department on road kills during the dry period of August to October 2013 showed that a total of 30 mammal species were killed by vehicles, of which 9 were carnivores, 1 primate and 19 herbivore species (Table. 4).

Table 1: Number of mammal species killed by vehicles on a tarmac road through MINAPA from April-June 2014

S/n	Common name	Scientific name	April	May	June	Total
1	Impala	*Aepyceros melampus*	1	3	0	4
2	African Hare	*Lepus crawshayi*	2	5	4	11
3	African civet	*Viverra civetta*	1	3	2	6
4	Spotted hyaena	*Crocuta crocuta*	1	1	1	3
5	Cape Buffalo	*Syncerus caffer*	0	1	0	1
6	Bush duiker	*Sylvicarpa grimmia*	1	0	0	1
7	Bohor reedbuck	*Redunca redunca*	1	0	0	1
8	Black-backed Jackal	*Canis mesomelas*	1	0	0	1
9	Miombo Genet	*Genetta tigrina*	3	2	4	9
10	Yellow Baboon	*Papio cynocephulus*	3	1	7	11
11	Shrew spp	*Elephantulus spp*	1	1	0	2
12	Lion	*Panthera leo*	0	2	0	2
13	Porcupine	*Hystrix spp*	0	1	0	1
14	Rat	*Unidentified*	0	0	2	2
15	Mangoose	*Unidentified*	0	0	1	1
	Total		**15**	**20**	**21**	**56**

Table 2: Number of bird species killed by vehicles in a tarmac road through MINAPA from April-June 2014

S/n	Common name	Scientific name	April	May	June	Total
1	Birds	*Unidentified*	0	0	5	5
2	Ring necked dove	*Strepttopelia capicola*	1	0	0	1
3	Lilac breasted roller	*Coracias caudatus*	0	0	1	1
4	Helmeted Guinea fowl	*Numida meleagris*	1	3	1	5
5	Francolin	*Francolinus spp*	0	3	2	5
6	Nightjar	*Unidentified*	**0**	**0**	3	3
7	Thick-knee	*Burhinus spp*	**0**	**0**	1	1
8	Eagle	*Unidentified*	**0**	**0**	1	1
9	Hornbill	*Tockus spp*	**0**	**0**	1	1
	Total		**2**	**6**	**15**	**23**

Table 3: Reptiles & Amphibians killed by vehicles in a tarmac road through MINAPA from April-June 2014

S/n	Common name	Scientific name	April	May	June
1	Monitor lizard	*Varanus niloticus*	0	0	2
2	Snake	Unidentified	1	0	2
3	Python	Unidentified	0	1	0
4	Toad	Unidentified	0	0	1
	Total		**1**	**1**	**5**

Table 4: Number of mammal species killed by vehicles along a tarmac road through MINAPA from August to September, 2013

S/no	Common name	Scientific name	August	September	October	Total
1	Impala	*Aepyceros melampus*	8	1	4	13
2	African Hare	*Lepus crawshayi*	2	1	0	3
3	African civet	*Viverra civetta*	2	2	0	4
4	Spotted hyaena	*Crocuta crocuta*	1	1	1	3
5	Buffalo	*Syncerus caffer*	0	0	1	1
6	Yellow baboon	*Papio cynocephalus*	1	1	0	2
7	Wild cat	*Felis sylvestris*	1	0	0	1
8	Bushbuck	*Tragelaphus scriptus*	1	0	1	2
9	Black backed Jackal	*Canis mesomelas*	0	1	0	1
	TOTAL		**16**	**7**	**8**	**30**

(Source: MINAPA Ecology Dept.)

Age and sex and position of wildlife road kills in MINAPA

The proportion of animals killed per age was 45.5% adults, 3% juveniles and 51.5% of animals killed could not be assigned any age as they were completely crushed. A statistical test using ANOVA indicated significant differences between age groups (P =0.01322). Tukey's pairwise comparison indicated a slight difference between the number of adult and unidentified animals (P= 0.04397). There was a significant difference between juveniles and unidentified (P= 0.01854). Results by Shannon Index method on the evenness on road kill species indicated the ratio of adult (2.433), juvenile (0.693), unidentified (2.008) and young (0). Field observation revealed that most of the unidentified kills were completely crashed by vehicles and identification of sex or age was not possible; and mainly included small mammals, birds, rats, genets, mongoose and hares. The highest numbers of road kills were most large mammals killed at an adult stage. Kills of buffalo, hyenas, porcupines and shrews were all adults, where as a single kill of baboon at young stage was recorded. Position of animals killed on the road showed no significance differences among right, centre and left (P =0.05875). There was no significant difference between sex of animals killed (P= 0.1859). There was no significant difference (P=0.05875) on location of killed animals on the road (right, centre, left).

Vehicle speed, number and time spent to pass through the park

Analysis of vehicle speeds calculated by subtracting the recorded time of entry and exit at Doma/Kikwaraza gates for various vehicle showed an average speed of 77km/h for buses, 75km/h for saloon/sedan (Toyota Chaser, Mark II etc), 74km/h for medium sized vehicles (Land Cruiser Hard Top, Prado, Nissan Safari etc), 67km/h for Min buses (Toyota DCM, Noah, Voxy etc) and 50km/h for lorries (Mitsubishi Fuso, Semi trailers etc). While the average speed for vehicles recorded by use of a speed gun for these categories of vehicles were 90, 83, 82, 77and 63 km/h for buses, saloons, medium size, min buses and lorry respectively.

The average time spent by vehicles to pass through the park during the day is shown on Table 5, medium sized vehicles spent the shortest time (0.32hrs) while mini buses spent more time to cross the park (0.50 hrs). The average time spent by vehicles to pass through the park at night is shown on Table 6, medium sized vehicles spent the shortest time (0.48hrs) while lorries buses spent more time to cross the park (0.56 hrs). Using a land Cruiser hard Top, and by adhering to all park regulations regarding speed limits and signboards in the park, this study recorded an average time of 0.63hrs for a vehicle to pass through the park during the day time (Table 7).

Table 5: Average speed and time taken by vehicles to pass through the park (Doma entry gate) during day time

S/no	Vehicle category	Average speed (km/h)	Time spent (hrs)		
			Average	Max.	Min.
1	Buses	81	0.55	1.15	0.35
2	Min buses	77	0.70	0.93	0.50
3	Lorries	77	0.89	1.92	0.42
4	Medium sized	105	0.61	1.35	0.32
5	Saloon	92	0.59	0.88	0.37

Table 6: Average time spent by various vehicle categories through the park during night time

S/no	Vehicle category	Average time spent (hr)	
		Doma-Kikwalaza	Kikwalaza-Doma
1	Buses	0.51	0.56
2	Min buses	0.57	-
3	Lorries	0.57	0.55
4	Medium sized	0.48	0.49
5	Saloon	0.58	0.44

Table 7: Average speed of vehicles recorded by a speed gun

S/no	Vehicle category	Average speed (km/h)
1	Buses	90.09
2	Min buses	77.67
3	Lorries	63.34
4	Medium sized	82.35
5	Saloon	83.55

The average numbers of vehicles passing through the park per day are shown in Table 8. Most vehicles passed through the park during the day time (56%) than at night time.

Table 8. The average number of vehicles passing through MINAPA for one day

S/no	CATEGORY	TIME-1	ENTRY	NUMBERS	TIME-2	ENTRY	NUMBER	TOTAL
1	B	D	DM	73	N	DM	2	75
2	MB	D	DM	21	N	DM	10	31
3	MS	D	DM	129	N	DM	59	188
4	L	D	DM	177	N	DM	194	371
5	S	D	DM	24	N	DM	57	81
6	B	D	KZ	63	N	KZ	3	66
7	MB	D	KZ	29	N	KZ	18	47
8	MS	D	KZ	115	N	KZ	71	186
9	L	D	KZ	330	N	KZ	301	631
10	S	D	KZ	33	N	KZ	49	82
TOTAL				994			764	1,758

D = day time, N = night time, DM = Doma gate, KZ = Kikwalaza gate

Spatial pattern of wildlife road kills in MINAPA from April to July 2014

There was no significant different on the spatial location of killed animals (P>0.05) along the road section, although slightly more animals were killed on the section between Doma gate and the park main entry. Detailed analysis showed that this road section has few huge speed humps as the eastern side of the road, the road is straighter and the area is more or less composed of open wood land factors that might be encouraging over speeding in the road section.

Perception of stakeholders on the impacts of road on wildlife and littering in the park

Survey of the main impacts of the road in the park showed that 32.3% (n = 251) was road kills, 25.9% wastes/littering, 17.52% change in animal behaviors, and 16.32% was on people feeding wild animals. The main causes of such impacts from the respondents view were low level of awareness on the value of wildlife (25%), over speeding (37.8%) and negligence (37.2%) of road users especially drivers. In order to reduce the impact of the road on road kills and littering, 30.4% of respondents recommended that road users should abide to park regulations and about 21.5% said that the road should be diverted so that it passes outside the park; others recommended improved awareness (20.4%) and intensive road patrol by rangers in the park (14.9%). The rest of respondents (12.7%) gave other alternative control measure. The main advantage given to benefits of diverting the road were to reduce impacts of the road on wildlife and littering (66.67%), increase wildlife population (11.10%), improved livelihood of communities where the diverted road will pass

(9.09%), provision of more space for animals (6.06%), reducing poaching (4.05%) and remove free tourism for road users while passing the park (3.03%).

Respondents who disagreed on the road to pass outside the park gave the following disadvantages, 48.16% said that it will increase travelling time and costs, 17.28% said it will result into reduced income to the current dwellers of Doma and Mikumi town as most of them are business men and women. About 17.28%, reported that it will lead to lack of free game viewing when they pass through the park, reduced authentic value of the park (12.35%), increased immigrants to new developed areas where the road will go through (3.70%) and increased poaching (1.23%). The proposal of using an alternative route from Melela – Kimamba to Mikumi town will have *140.6 km while the* distance from Melela to Mikumi town via Mikumi National Park is *89.7 km* with a difference of *50.9 km.* Using this alternative road will assist to control the already pointed out negative impacts to the park but will also stimulate local economy to the neighbouring local community in Kilosa District.

Wastes/littering in the park

A total of 415 kg of solid waste was collected for three days of the study, which is an average of 138.3 kg per day and 4,149kg per month (Table 9). The amount and type of wastes collected along the road from April to June 2014 is shown in Table 10. The largest proportion of solid wastes collected (by kg) composed of vehicle tyres and tubes (70.36%) and glasses and mirrors (10.36%).

Table 9. Type and amount of wastes collected in the park in a period of three days during the study

S/N	Waste category	Amount in (Kg)	Percentages
1	Plastic bottles	22	5%
2	Empty tins	4	0.96%
3	Tyres and tubes	292	70.36%
4	Metal materials	14	3.37%
5	Glasses and mirror	43	10.36%
6	Papers and boxes	20	4.82%
7	Plastic bags	15	3.61%
8	Clothes	4	0.96%
9	Wood	1	0.24%
	Total	**415**	**100%**

Table 10: Amount and types of wastes collected along the road from April- June 2014 by the ecology department in MINAPA

S/N	Waste Category	April	May	June	Total
1	Plastic bottles	70	76	497	**643**
2	Empty tins	18	35	68	**121**
3	Plastic bags	1.6	16	29.5	**47.1**
4	Paper and boxes	14	17	59	**90**
5	Tyre and tube	415	498	898	**1811**
6	Metal materials	223	177	268	**668**
7	Glass and mirror	47	20	83	**150**
8	Wood	100	0	34.5	**134.5**
	Total	**888.6kg**	**839kg**	**1,937kg**	**3,664.6kg**

(Source MINAPA Ecology Department)

DISCUSSION

This study has shown road kill of 29 fauna per month (about one road kill per day) during three months of the study. The road kills per month in 2014 are over and above road kills per month in 2011, which was an average of 3 kills per month (Marttila in 2011). Another monitoring conducted by the park authority form 1992 – 1997 indicated an average of 7 kills per month. According to Mziray (2011) an average of 12 fauna were killed per month in the park from 1992 - 2008. The increase in the number of fauna killed by vehicles per month over time is a concern to biodiversity conservation and park management. Therefore, mitigation measures are required in order to stop this increasing trend over years. The increase in the number of animals being killed by vehicles per month in the park might be due to increasing number of vehicles passing through the park per day, increasing vehicle speed for modern vehicles, increasing negligence of drivers for park regulations and road signs, and to some extent deterioration of speed control measures like speed humps and warning signs.

This study has shown that the average speed of vehicles through the park was 77-105km/hr during the day; and therefore most vehicles (except few big lorries) are over speeding. This is against the speed limit set by the park authority of 70km/hr during the day and 50km/hr at night. During the daytime, most buses were recorded to be crossing the park through the Doma gate (73 lories on average) as compared to Kikwalaza gate (63 lories on average). Over speeding of vehicles may be due to longer distance left to travel on either side of the road for drivers to reach their final destination, e.g. 296 km from DSM to Mikumi and about 501km and 851km to Iringa and Mbeya towns respectively. The study also has shown that the largest number of vehicles passing through the park during the day are lorries (235 on average); that had an average speed of 63km/hr.

Participant observation and interviews during this study has shown that most drivers are not observing the recommended vehicle speed and warning signs placed at various points in the park to indicate animal crossing etc. In this case, it is obvious that most of the road kills are caused by over speeding, ruthless driving and failure of drivers to abide to park recommended speed and warning signs. Over speeding and increased road kills over years might be related to improvement of the road over years; where it was a rough road before 1976, re-surfaced between 1977 and 1978 and then it was put to tarmac status from 1990 to 1991 (Marttila, 2011). Therefore, increased road kills is a combination of improvement of the road and increase in the number of vehicles over years. The tremendous increase in the number of vehicles passing through the park per day is anticipated to continue and road kills to increase over years to come due to improvement in household income, that is coupled with increased ability of households or individuals to purchase vehicles in Tanzania. In this case, it appears that the road might not be in a position to accommodate the so heavy traffic volume leave alone the forecasted impact on wildlife ecology of so many vehicles especially on resource use and reproduction.

This study has shown that the minimum time required to cross the park is 0.63hrs. Looking at the time spent by most vehicles (0.32h - 0.58h), the study has shown that most vehicles are over speeding when crossing the park as they are spending less time than recommended to cross the park. Therefore, it is imperative to find more effective means to enforce drivers to adhere to park regulations especially vehicle speed; and that all efforts to curb over speeding should be directed during the day time.

This study has shown an average 1,758 vehicles passing through the park per day and that most of vehicles pass during the day time. The high number of public vehicles during the day is due to the fact that national regulations for public passenger vehicles do allow buses to travel only during the day. The average time spent by buses during the day time (0.55h) and night (0.54h) to pass through the park did not vary so much showing that presence or absence of traffic police patrol has no influence to drivers; with temporal exceptions of drivers alerting each other to reduce vehicle speed upon citing traffic police in the park.

This study has shown that about 138.3kg of solid waste being littered in the park per day (about 4,149 kg per month), and it is anticipated that the amount of wastes per day will continue to increase due to increasing number of vehicles over years in Tanzania. The lower amount of waste collected per month by the ecology department than this study might be due to diurnal and seasonal variation on wastes in the park. The collection of more wastes near road/speed humps might be due to the fact that vehicles tend to reduce speed at road humps giving room for passengers an opportunity to throw wastes out of vehicles through windows. This study and data from the ecology department has shown that waste disposal on the road in the park is a serious and long standing challenge to the ecological integrity of the park. Due to many vehicles through the park per day, huge volumes of litter is thrown by road users within short intervals, thus making it difficult for the road to be free of waste in any day.

It is concluded that the Tanzania-Zambia road has significant negative impact to Mikumi National Park, in terms of wildlife road kills, wastes, costs of waste and road kills collection and incineration, and biodiversity conservation at large; and that the negative impacts are increasing over years.

CONCLUSION & RECOMMENDATION

From the current study as well as data from the ecology department, it is concluded that wildlife road kills and wastes has reached an alarming stage in Mikumi national park due to increased wildlife mortality, increasing wastes per month as well as tarnishing ecology and health of the park. This is exacerbated by the fact that costs of removing road kills and waste management have increased tremendously and will soon be out of the ability of the park financial capacity. Therefore, we recommend the following measures to be instituted at various time frames in order to safeguard the integrity of the park as well as ensure viable wildlife populations in the park.

RECOMMENDATIONS

SHORT TERM/IMMEDIATE CONTROL MEASURES

1. Embark on awareness campaign to passengers, community members and drivers on the impact of road kills in the park, impact of wastes in the park and adherence on park regulations. The park should create education materials to be given to road users when entering Mikumi national park.
2. Institute a condition for each passenger vehicle driver to announce to passengers that '*Now you are entering Mikumi national park where you are not allowed to through wastes outside the vehicle and that any violation will be subject to fine*'.
3. Institute a condition that all vehicles passing through Mikumi national park should have a waste collection bin for passengers.
4. The park should increase the fine for passengers and drivers for road kills and littering in the park.
5. All road signs in the park that are in poor condition should be replaced with news signs that are clear, good and easily visible by road users; and that more warning signs should be placed along the road.
6. All speed humps that have deteriorated and not effective to reduce vehicle speeds should be rehabilitated so that they are effective and where necessary put more speed humps let us say every after 1.5km.
7. Construction/addition of more big speed humps or turning the small speed humps into big humps because the small speed humps appears to be not effective for reducing vehicle speeds.
8. Increase vigilance through more daily park road patrols by rangers for law enforcement and to increase fear for road users.
9. Strengthen collaboration with traffic police to enforce compliance to regulations by road users and penalize road users for violation of park regulations.
10. Strengthen regular systematic waste removal from the park through use of casual labours or by contracting a company for collection of wastes in the park.

LONG TERM CONTROL MEASURES

1. Diversion of the road from Melela to Kilosa via Kimamba to Mikumi in order to eliminate road kills, stop littering in the park and enhance ecological integrity of the park (this stretch will add up 59 km). This option are will also prevent easy access/ entry by poachers in the park, reduce introduction of invasive/ exotic species in the park, reduce

habituation of animals due to feeding, prevent introduction of diseases as the result of feeding, the diverted road will stimulate economic growth of some centres along the new road due to access to markets and reliable transport. It is presumed that the diversion will also have a big economic impact to communities adjacent the road especially the undeveloped, unprivileged landlocked Afro Arab town of Kilosa.

2. Institution of a fee for payment of ecosystem health that will be used to control environmental pollution in terms of waste and emissions. The fee paid should be used for waste removal, removal of road kills and park patrols to control road kills and littering.
3. Operationalize use of manual entry and exit gates in order to record entry and exit time of vehicles in order enforce compliance to the recommended time to be spent by vehicles through the park by park staff being placed at one gate to record time of entry into the park and another staff to record the time of exit from the park (with the two staff communicating to ensure compliance). This should be coupled with expansion of the gates on both sides to create enough parking areas during entry or exit especially at peak vehicle hours.
4. Construction of automatic entry and exit gates that use smart cards that records entry and exit time in order to enforce compliance to the recommended time to be spent by vehicles through the park. This should be coupled with expansion of the gates on both sides to create enough parking areas during entry or exit.
5. Placement of radars along the road to recording vehicle speed and littering and penalize road users who violate park regulations.
6. Construct tunnels at major crossings of wildlife in the park so that animals can pass though easily.

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THE MAGNITUDE AND VULNERABILITY OF VERTEBRATES' ROAD KILL IN THE SERENGETI ECOSYSTEM, NORTHERN TANZANIA

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ABSTRACT

Road kills affect the sustainability of many wildlife species worldwide, however surveys on road kills have been more in developed countries. In developing countries like Tanzania, although wildlife populations are susceptible to road kills, little information is available. We report results from a road kill survey of terrestrial vertebrates in the Serengeti ecosystem, conducted using direct observation method using road transects in wet season between March and April 2015 covering a total length of 720km. A total of 19 road kills were recorded, including mammals (58%; n = 16) and avifauna (42%) from a total of 16 wildlife species. On average road kill was equivalent to one vertebrate in every 40km per day. Out of five transects, more kills were found along the Seronera-Fortikoma and Seronera-Naabi transects. Wildlife on these transects are susceptible to road kill probably because of overspeeding. More fresh carcasses were observed in the morning than the rest of the day. The results have suggested that road kill has significant impact on the biodiversity of the ecosystem. Therefore, further studies are recommended to establish trends and factor(s) responsible for such kills. Furthermore, stakeholders and Management Authorities are advised to adhere to protected areas regulations.

Keywords: Biodiversity, road kill, Serengeti ecosystem, vertebrates, wet season

INTRODUCTION

Roads traversing through protected areas have adverse impact on wildlife (Bissonette & Kassar, 2008; da Cunha *et al.*, 2010; Santos *et al.*, 2011; Selvan *et al.*, 2012). Road kills have been reported to occur in different protected areas worldwide (Drews, 1995; Carvalho & Mira, 2011; Teixeira *et al.*, 2013; Collinson et al., 2014), and have tremendously increased concurrent with increase in infrastructure development (Dodd et al., 2004; Selvan et al., 2012; Morelle et al., 2013). However, more information is available in developed regions (Orlowski, 2005; Glista & DeVault, 2008; Freitas *et al.*, 2013; Morelle *et al.*, 2013). Consequently, road conditions, traffic volume, poor visibility and speed influence the road kill rates (Forman & Alexander, 1998; Dodd et al., 2004; Kioko et al., 2015b). The diversity of species killed by vehicles in protected areas is higher in tropics, and thus the conservation issues may become more relevant (Farmer & Brooks, 2012; Freitas et al., 2013). Previous studies have found that road kills do not occur randomly but are spatially clustered because wildlife movements tend to be associated with specific habitats, terrain, and adjacent land use types. Vertebrates that are often hit by vehicles are those which are attracted to spilled grain, road side plants, insects, basking animals, small mammals, road salt or dead animals (Forman & Alexander, 1998; Freitas *et al.*, 2013). Understanding the species or vertebrate communities that are susceptible to road-kill is important for sustainable conservation. Though, there is much data on road kills in some protected areas in Tanzania (Drews, 1995; Kioko et al., 2015a; Kioko et al., 2015b), no information has been documented in the Serengeti ecosystem. Therefore, this study aimed at investigating the species involved, magnitude and patterns of road kills in the main roads of Serengeti ecosystem.

MATERIALS AND METHODS

Study area

The study was conducted in the Serengeti ecosystem in northern Tanzania. The ecosystem extends to south-western Kenya between 1° and 3° S and 34° and 36° E (Figure1). It spans some 30,000 km² and forms one of the important cross-border conservation regions in the world. The Serengeti ecosystem has about 70 larger mammal species (McNaughton, 1985; Sinclair & Arcese, 1995) and more than 600 avifauna species (Nkwabi, 2015; Nkwabi et al., 2015), and supports one of the largest herds of migrating ungulates and the highest concentrations of large predators in the world (Sinclair & Arcese, 1995; Kideghesho et al., 2006).

Figure 1: *Map of the Serengeti ecosystem showing the study transects*

It's high diversity in terms of animal species is a function of diverse habitats ranging from riverine forests, swamps, kopjes, open grasslands and woodlands. The south-eastern part of the area is open grassland, the northern part largely wooded, and the western region a mix of open and wooded areas. The open grassland zone receives inadequate rainfall to sustain fire, typically below 600 mm per year (Homewood et al., 2004). Under normal circumstances, almost all the rain falls in two seasons, a short season (November-December) and a longer one (March-May). However, in some years inter-annual variations are inevitable especially due to effects of climate change. The woodland, which is occasionally interspersed with patches of tall open grasslands, receives an annual maximum rainfall of 1100mm per year. Its high diversity in terms of species is a function of diverse habitats ranging from riverine forests, swamps, kopjes, grasslands and woodlands. In general, the Serengeti woodlands are mainly composed of *Acacia*, *Balanites* and *Commiphora* species with other broad leaved species such as *Terminalia*, *Euclea* and *Croton* as sub-dominates (Herlocker, 1976). Species are dominated the intermediate grasslands and woodlands. The topography in short is highly variable, with catena effects having important influences on woody species.

Study design

The study transects were selected along the main roads which are frequently used by vehicles in the Serengeti ecosystem. A total of five transects each with 40km long were established. These transects were: (i) Naabi-Olduvai, (ii) Naabi-Seronera, (iii) Seronera-Fortikoma, (iv) Seronera-Ndabaka and (v) Seronera-Lobo. Each road transect was divided into three sections, the left-hand edge, the center of the road, and right-hand edge. The three edges of the road formed the standard road sampling width. Nine sampling points were established within a road transect at an interval of 5km whereby the width of each road was measured at each point. The survey was conducted in the wet-low tourist season (March-April 2015). We performed morning (7:30-11:30am) and afternoon (2:00-6:00pm) sessions of road kill detection for each transect. The targeted species were all vertebrates from four taxonomic groups (Amphibia, Reptilia, Aves and Mammalia).

Data collection

Prior to commencement of data collection the vehicle odometer was set to zero and recorded manually all the required information including the transect name, GPS start location, start time, transect length, width, date, season, session and recorders names. The vehicle was then driven at a speed of about 40 km/hr as described by Collinson et al. (2014). In order to have a close road kill estimates, Collinson et al. (2014) recommended starting road kill surveys as early in the day as possible. Their study suggested that road kill sampling was most effective between 1.5 hours after dawn and 1.5 hours before dusk due to possibility of less damage to and/or removal of the road killed animals if surveys start at dawn apart from observers' failure to detect all carcasses (Slater, 2002; Teixeira et al., 2013). The four observers in the car were facing forward and scanned on either side of the road each from the center of the car bonnet to the road edges to locate any carcass, injured or live animal on the road. Once, a carcass was spotted either along the road or on the road verges, the observers stopped the car and disembarked for data collection including animal species, GPS location, time, odometer reading, carcass condition, road width at the kill, number killed, zone, estimated age class, sex, road conditions, habitat type, scavengers if present, distance to nearest tree cover (m), rainfall, verge grass height (cm), verge grass colour, temperatures (°C) and wildebeest/zebra migration. In addition, the animal killed or injured was photographed. After collecting all required data from the carcass, it was removed to avoid double counting. The equipment used for data collection included a ranger finder; measuring tape, weather station device, camera, speed gun, mobile freezer, dissecting kit and GPS.

Data analysis

Statistical Package for Social Science (SPSS, version 17.0) software was used for analyzing the data. Kolmogorov's test was used to test for normality of data. The differences in road kill among transects was compared using ANOVA test. Descriptive statistics was used to summarize the data. Road kill rate was expressed as individuals/km/day.

RESULTS

Magnitude and vulnerability of road kills in the Serengeti ecosystem

The survey detected a total of 19 vertebrates road kills comprising 16 species, meaning that for every surveyed transect, at least one animal was killed. Overall, road kill in the study area accounted for a rate of 0.0132 animal/km/day. The proportion of mammal species killed was higher 58% (n = 11) than bird species 42% (n = 8) as shown in Table 1.

Table 1: Vertebrate species killed along the surveyed road transects in March and April 2015 in the Serengeti ecosystem.

Mammals			
Common name	**Scientific name**	**Number observed (n)**	**Proportion (%)**
Bat eared fox	*Otocyon megalotis*	1	5.3
Black-backed jackal	*Canis mesomelas*	1	5.3
Kirk's dik dik	*Madoqua kirkii*	1	5.3
Brown hare	(*Lepus capensis*)	1	5.3
Thomson gazelle	*Gazella thomsonii*	2	10.5
Warthog	*Phacochoerus africanus*	1	5.3
Wildebeest	*Connochaetes taurinus*	2	10.5
Zebra	*Equus burchelli*	2	10.5
Total		**11**	**58%**
Birds			
Flappet lark	*Mirafra*	1	5.3

	rufocinnamomea		
Brown-crowned tchagra	*Tchagra australis*	1	5.3
Crested francolin	*Francolinus sephaena*	1	5.3
Fischer's sparrow-lark	*Eremopterix leucopareia*	1	5.3
Grey-backed fiscal	*Lanius excubitoroides*	1	5.3
Ring-necked dove	*Streptopelia capicola*	1	5.3
Secretary bird	*Sagittarius serpentarius*	1	5.3
chestnut-bellied sandgrouse	*Pterocles exustus*	1	5.3
Total		**8**	42%

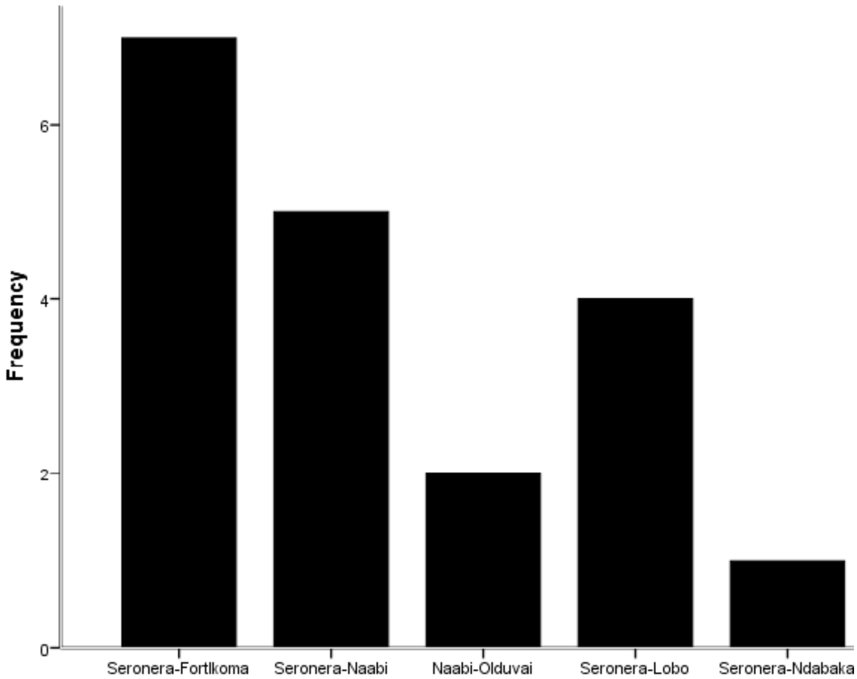

Figure 2: *The frequency of road kills occurred at different study transects in wet season*

Spatial-temporal patterns of road kills in the Serengeti ecosystem

The results showed that of all transects, the Seronera-FortIkoma transect had the highest frequency of road kill while the Seronera-Ndabaka transect had the lowest (Figure 2). The differences on road kills among transects were statistically highly significant (ANOVA; $t = 7.558$, $df = 18$, $P < 0.001$).

Vertebrates road kill during the morning session 53% (n = 10) and afternoon session 47%, (n = 9) were closely related. In addition, more of the carcasses were fresh 63% (n = 12) compared to the old ones (n = 7, 37%). Most of the road kills (89%) were found on good road segments whereby 47% were in grassland and 37% in wooded grassland (Figure 3). In addition, most of the road kills were found when there were roads were dry 74% (n = 14) at the time of sighting. There was a higher proportion of road kills in greener 53% (n = 10) than brown 37% (n = 7) grass colour.

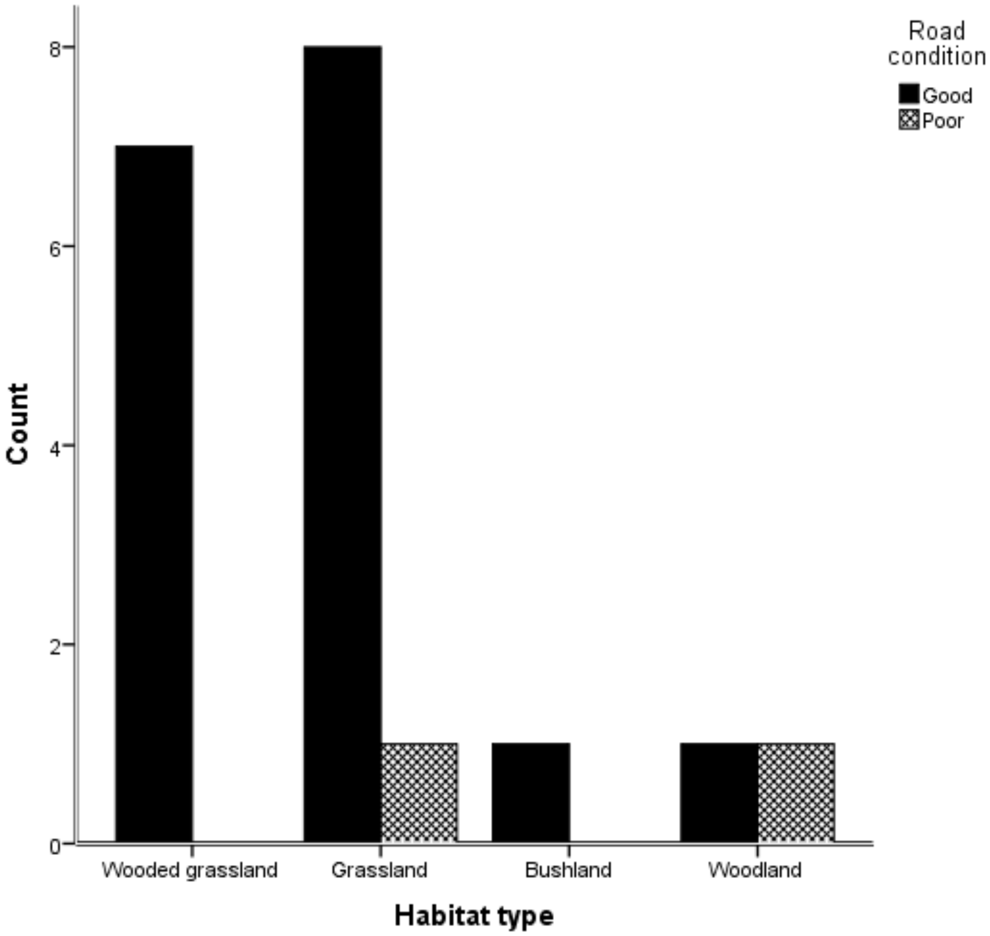

Figure 3: *The number of road kills observed on different road conditions between different habitats in the study area.*

DISCUSSION

The magnitude and vulnerability to road kills in the Serengeti ecosystem

Road kill is notoriously known as one of the visible impacts of roads on animal populations, with a wide range of taxonomic groups being killed every year. We report road kill results for the Serengeti ecosystem. A significant number of vertebrate kills incidences were recorded indicating that road networks have a critical role on species viability in the ecosystem. Road kills were reported to cause great impact on threatened or endangered species such as the African wild dog - *Lycaon pictus* (Creel & Creel, 1998). Our findings concur with previous studies in other protected areas (Drews, 1995; Creel & Creel, 1998; Forman & Alexander, 1998; Coffin, 2007; Gerow et al., 2010), that road kills affect the sustainability of many wildlife species. Furthermore, higher numbers of mammals than birds were killed suggesting that the former are more vulnerable to road kill than the later. Forman & Alexander (1998), showed that mammals are more attracted to roads than birds because of, road side plants, drinking rain water road salt or dead animals. In this study, we encountered a number of mammal species using road verges for obtaining green forage. Other mammal species such as bat eared fox and black backed jackal were probably killed while scavenging on carcasses along the road. However, this could also be attributed to inability of mammals to escape from over speeding vehicles, corresponding with other findings (Bouchard et al., 2009; Chambers et al., 2010; Lima et al., 2015). Adult animals were more prone to road kill probably due to their high numbers, confidence and inability to escape because of weight compared to juveniles. This call for the need to identify species at high risk and road stretches where to concentrate mitigation actions.

Spatial-temporal pattern of road kills in the Serengeti ecosystem

The differences in mortality from road kill we observed could be attributed to differences in vegetation types, visibility, terrain, road conditions and presence of dietary attractants. In our survey, the Naabi-Olduvai is located in the south eastern plains which receive an annual rainfall of <600mm (Sinclair et al., 2002; Homewood et al., 2004) making the area relatively drier, thus road verge has more effect in attracting animals. This could have contributed to the observed high number of road kills. Conversely, the higher road kills in the Seronera-Fortikoma were probably contributed by poor visibility due to presence of wooded vegetation (woodlands and bush lands). Moreover, differences in behavioral response amongst vertebrate species could also contribute to road kills. For example male and juvenile vertebrates have been implicated to road accidents (Putmam, 1997). Although the visibility and traffic volume of the Seronera-Naabi is similar to the Olduvai-Naabi transect, the former has relatively poor forage quality (Hopcraft et al., 2010) which do not attract many animals along road verges, an indication for the lower kills recorded along this transect. The Seronera-Lobo and Seronera-Ndabaka transects have similar features with relatively lower traffic volume and bad terrain; attributing to the lower number of road kills. Contrary to other studies on road kills (Dussault et al., 2006) our results do not reflect the expected seasonal pattern as it covers only the wet season. However, on the daily basis the morning sessions indicated a higher detection of road kills probably because animals are more active in the morning concurrent with high traffic volume.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

This is the first study, which has brought an insight on the magnitude and distribution of road kill in the Serengeti ecosystem. Therefore, the estimates reported are critical and should be considered for monitoring and mitigation of the impacts of road-kill in protected areas. However, the findings reported here might be underestimated because some carcasses could have been missed (uncounted) and other people and/or scavengers may have removed some. We conclude that traffic volume has considerable effect on wildlife species within the Serengeti ecosystem.

ACKNOWLEDGEMENTS

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PREDICTING FACTORS CONTRIBUTING TO CROP RAIDS BY ELEPHANTS IN AMBOSELI ECOSYSTEM, KENYA

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ABSTRACT

Amboseli ecosystem hosts about 1,400 elephants most of which roam outside the national park. Elephant conservation faces pressure due to human population growth and land use changes. Rainfall patterns in the ecosystem do not support cultivation. Most of the cultivation is done in the wetland areas under irrigation. This scenario has led to increasing crop raids by elephants which threatens local economy as well as elephant populations through retaliatory attacks. This study used crop raiding data, geographical information system (GIS) and remote sensing to identify features contributing to crop raid occurrences by elephant. Binary logistic regression model was developed using presence and absence crop raids incidences by elephants collected by scouts between January 2013 and August 2015. Only georeferenced data were used. A convex hull for presence data was created and an area within it was excluded when generating absence data. The absence data was randomly distributed two kilometres outside the convex hull but within the six targeted Amboseli group ranches. Qualitative feature shape files were converted to distance data. Results showed that crop raiding was determined by water surface points, distribution of settlements, towns, scout and ranger outposts, clay soil, extent of cultivation, ranches, elephant corridors and routes and woodlands. Receiver operating curve (ROC) plots confirmed that the models fitted well with the data (AUC>0.9). Sustainable mitigation of crop raids by elephants can be achieved via long-term strategies that include proper land use planning where all stakeholders are fully involved. Also local communities should be supported and or encouraged to engage in alternative livelihoods which include ecotourism activities, which are conservation friendly.

Keywords: Amboseli ecosystem, crop raids, elephants, modelling

INTRODUCTION

Amboseli National Park is one of the prime parks visited for wildlife viewing with Mount Kilimanjaro on the background. In addition to its rich culture in the surrounding Maasai community, Amboseli is among the top tourist destinations in Kenya (Okello et al., 2014a; Ogutu et al., 2014). The African elephant (*Loxodonta africana*) is one of the main wildlife attractions not only in the park but also in parks and reserves in the country. Though, the elephant population had faced challenges which led to a decline, the population is currently increasing with about 1400 hosted in the Amboseli ecosystem (KWS, 2009; Kioko and Seno, 2011). However, about 80% of the population roam in the surrounding group ranches (Kioko and Seno, 2011; Ogutu et al., 2014). These group ranches act as a refuge area, dispersal or migratory route for the elephants from or to Amboseli National Park which is barely 392 km^2 (Kioko and Seno, 2011; Ogutu et al., 2014). The park size rarely supports the large wildlife populations forcing them to move out of the park to seek for more space exposing them to threats mounting from human population growth, settlements, land fragmentation and habitat loss (Mose et al., 2013).

Currently, Amboseli ecosystem is facing rampant and very fast need for ranch subdivision which have opened up for incompatible land use changes which is likely to hinder the elephant conservation (Ogutu et al., 2014). Maasai community were pastoralist by culture though they have over some time changed the practice due to changing climatic conditions (lack of pasture and limited water) and availability of alternative source of livelihood (Okello et al., 2014a; Ogutu et al., 2014). Lack of tangible benefits from wildlife conservation has also contributed to change in mind. Because of this, some of the group ranches have now been changed to other land use practices apart from been used as grazing fields for the livestock. Land subdivisions are coming up facilitating leasing of land for crop farming or land sales to non Maasai (NEMA, 2009). These have contributed to loss of wildlife habitat, blockage of corridors and more so conflicts between human, livestock and wildlife (Okello et al., 2014b).

Amboseli ecosystem is a semi-arid area where rain-fed agriculture is not highly supported apart from the areas on the slopes of Mount Kilimanjaro (Ogutu et al., 2014) where the soils are rich and fertile which supports a variety of crops. However, some areas especially close to water resources have been cultivated by farmers emigrating from other regions who have been given leases by the local Maasai community (Ogutu et al., 2014). This immigration has led to increase in crop production in the wetlands in Namelok and

Kimana areas (Okello et al., 2014; Ogutu et al., 2014; Kioko and Seno, 2011). The increased proceeds accrued from cultivation has have tempted other group ranches to subdivide their land. This kind of land use has messed up with the traditional setup of the area causing a rise in conflicts for space, water or right of way. Currently, human elephant conflict is souring each day which in return led to retaliatory attacks on elephants by the affected people.

The most reported human-wildlife conflict type worldwide is crop raiding more so by elephants (Pittiglio et al., 2013). Despite the interventions to mitigate crop raiding, these measures have not succeeded fully which calls for adoption of other approaches otherwise the elephant conservation will be in jeopardy in most regions (Graham and Ochieng, 2008). A holistic approach is needed which involves proper understanding of crop raiding patterns, making proper predictions and protection mechanisms (Pittiglio et al., 2013).

This study, therefore, aimed at determining the factors that contribute to crop raiding by elephants in the Amboseli ecosystem. Using the powerful tools of Geographical Information System (GIS) and remote sensing, binary logistic regression was used to model the probable predictor variables that contributes to crop raiding by elephants.

MATERIALS AND METHODS

Study area

Amboseli ecosystem which host Amboseli National Park (ANP) lies in southern Kenya, between 2°30′–2°45′ S and 37° 00′–37°30′E (Fig. 1). Many parts of the ecosystem are semi-arid characterized by receiving less than 300 mm of rainfall per annum which is erratic, high temperature (14 to 30° C) and frequent and prolonged droughts (Gichohi et al., 2014). The ecosystem forms a large land mass where large mammals roam or traverse freely in the six community ranches (Kimana, Imbirikani, Olgulului/Ololorashi, Kuku, Rombo and Eselenkei) owned by the Maasai community (Okello et al., 2014). The ecosystem covers an areas of 5,700 km^2 (KWS, 2009) and plays a big role in connecting various protected areas in the region which include Chyulu National Park to ANP, Tsavo West National Park to ANP or Kilimanjaro National Park, Arusha National Park to west Kilimanjaro and ANP to Magadi area.

Amboseli ecosystem hosts a variety of wildlife which includes about 1,400 elephants, array of ungulates (wildebeest, grant and Thomson gazelle, common zebra, eland, gerenuk, reedbuck), rich birdlife (400 species of which

40 are raptors), diverse carnivore population (lion, cheetah, leopard, spotted and stripped hyena, jackal, caracal, civet and serval cats), swampy and acacia mosaic vegetation (KWS, 2009, Kenana et al., 2013, Okello et al., 2015). Most of the water sources in the region are water springs that pops up in the lowlands emanating from underground water seeped in Mount Kilimanjaro (KWS, 2009). The water forms swamps and rivers which support the wildlife, livestock and human use (Ogutu et al., 2014).

Though Maasai were purely pastoralist, they have evolved recently to agro-pastoralist more so geared by the shift of wealthy definition from having many children and owning more livestock to amount of cash and land owned (Okello et al., 2014). Because of this, Kimana group ranch is almost fully subdivided while other group ranches are following suit (Kioko and Seno, 2011). Rain-fed agriculture is practiced only in areas close to Mount Kilimanjaro while other areas need use of irrigation to support crop production (Okello et al., 2014). Soils in the ecosystem are of volcanic origin which is highly saline and alkaline and can only support pastoralism and wildlife grazing (Okello et al., 2014). However, soils near water sources can be highly fertile (Katampoi et al., 1990; Okello et al., 2014) that can support crop production. This is evident in the expanding crop farming in the Namelok and Kimana wetlands which in turn has led to frequent crop raiding by wildlife especially elephants.

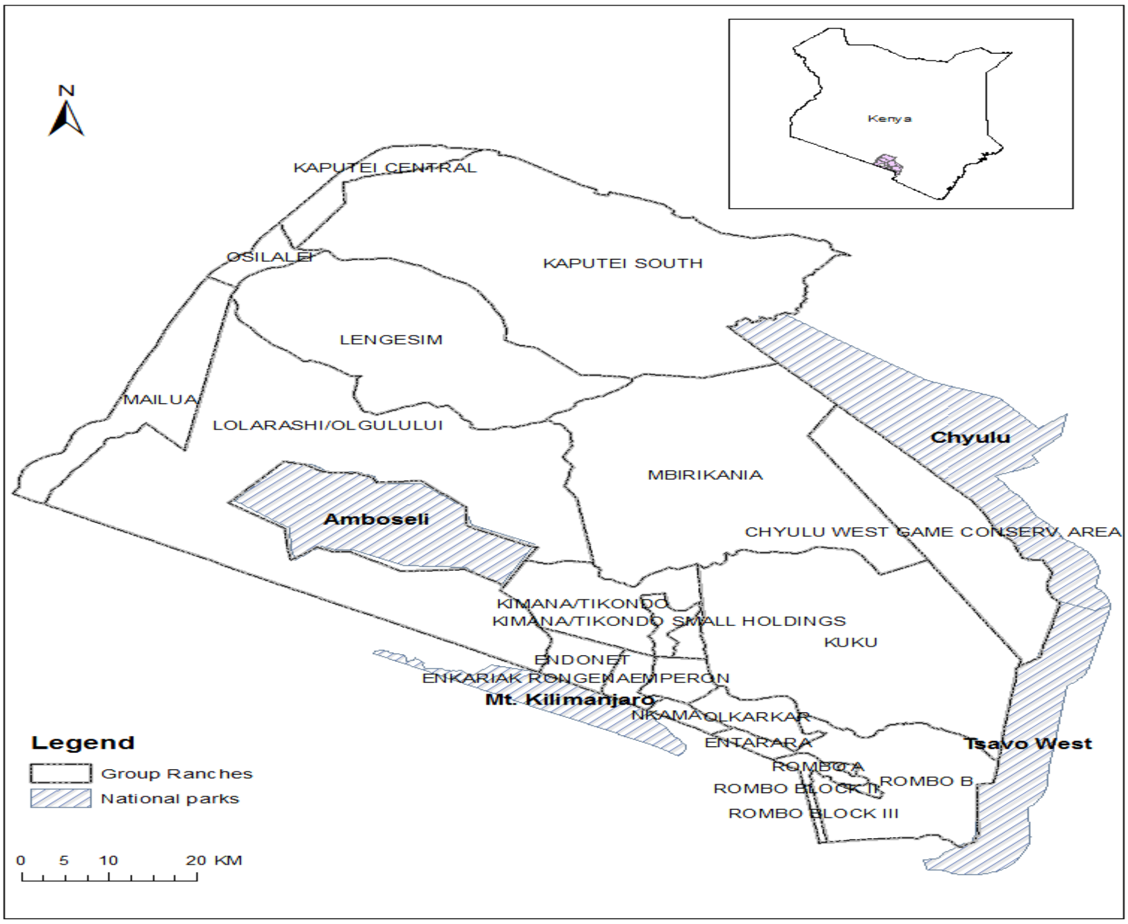

Figure 1: *Location of Amboseli ecosystem and respective group ranches and national parks*

METHODS

Monitoring of crop raiding

Trained community game scouts and rangers usually attend to human-wildlife conflicts within their areas of jurisdiction. To make sure this is done systematically and within a short time, scouts and rangers are stationed in outposts that were strategically designed to cover a specific area and also to offer a back-up to other teams. Scouts or rangers attending to human-wildlife conflict incidences are equipped with a standard data sheet, camera and a geographical positioning system (GPS) for recording conflict incidences. The conflict incidences are either encountered by scouts or rangers during patrols or are reported by farmers and verified by scouts. Among the attributes collected in relation to conflict include date, time when conflict occurred, coordinates, wildlife causing conflict, conflict type and if it is crop damage, crop type, acreage damaged, action taken among other variables.

For this analysis, only elephant crop raiding data with UTM coordinates and other attributes were selected. A total of 1,674 incidences of crop raids that occurred between January 2013 and August 2015 were used in the analysis.

Predictor variables

Factor documented by various authors that relate to crop raids by elephant were picked for model development. This includes three major categories which include factors contributing to elephant distribution, favour crop farming and human distribution (Smith and Kasiki, 2000; Hoare, 1999; Sitati et al., 2003; Wall et al., 2006; Graham et al., 2010). These factors include human settlement, scouts' and rangers' outposts, towns, national parks, community conservancies, forest reserve, group ranches, Kitenden corridor, elephant migratory routes, water sources (dams, water pans, waterholes, swamps, irrigation ponds, rivers), soil type (sandy soil, clay soils, loam soils, very clay soils), vegetation types (montane forest, woodlands, acacia vegetation), agricultural areas, rocky areas, Kimana small holdings, slope, altitude, roads, electric fences and Enduimet wildlife management area.

Respective variable shapefiles were processed in ArcGis 10 (ESRI, 2011) using data available (AWF, 2010; Kenana et al., 2013; ILRI, 2010; USGS, 2011). The shapefiles were transformed to world global system (WGS 84) and projected to Universal Traverse Mercator zone 37 south (UTM 37S) and clipped to the study area. Further, the vector shapefiles were converted into raster files of cell resolution of 30 meters. Qualitative rasters files were converted into Euclidean distances to make them quantitative rasters. A slope map (in degrees) was processed from the digital elevation model (DEM).

Model development

We used presence (crop raiding) and absence (no crop raids) data to develop the model. Absence data were computer generated and randomly selected from areas where crop raiding did not exist. A 2 km buffer was created around crop raid data with overlapping buffers dissolved. The buffer polygon was excluded from the study area polygon giving rise to a no crop raiding polygon. A total of 1,674 randomly un-stratified points were created to form the pseudo-absence data (Greaves, Sanderson & Rushton 2006; Barbet-Massin et al. 2012; Kimanzi et al., 2013). A shapefile containing presence and absence data was created and later on randomly split into two: train and test data in the ratio of 7:3 (Huberty, 1994; Sarhangzadeh *et al.,* 2013, Kimanzi *et al.*, 2013). Train data was then used to develop the model.

Using train data, values of each variable were extracted where the presence and absence points coincides. The values were input into SPSS version 18 (IBM, 2009) for statistical analysis. A binary logistic regression analysis was used to predict presence or absence of crop raids by elephants (Sitati et al., 2003; Estes *et al.*, 2011; Kimanzi *et al.*, 2013, Sarhangzadeh *et al.*, 2013). Dependent variable was coded as 1 for presence and 0 for absence. The best model was selected using a forward stepwise (Wald) method. The model with maximum possible variables that were significant ($P<0.05$) was selected. In addition multi-collinearity was tested using variance inflation factors (VIF) to make sure the variables were independent. Their respective variable coefficients were used in predicting the crop raids using the expression below.

$$y = (\exp(\beta_0+ \beta_1 x_1+ \ldots\ldots\ldots \beta_n x_n))/(1+(\exp(\beta_0+ \beta_1 x_1+ \ldots\ldots\ldots \beta_n x_n)))$$

Where the dependent variable (y) was coded as 1 for presence and 0 for absence while x_1, x_2, ……x_n were independent predictor quantitative raster maps, and β_0, β_1,……….. β_n were logistic regression coefficients (Hosmer and Lemeshow,2000; Sarhangzadeh *et al.*, 2013).

The output index map was generated with values ranging from 0 (least susceptible to crop raids) to 1 (most susceptible to crop raids) (Kinear and Gray 2000; Sarhangzadeh et al., 2013; Latif et al., 2013).

The significance of the independent parameter coefficients and goodness fit of the model was tested by use of Wald statistics and Hosmer and Lemeshow (2000), respectively, while the accuracy of prediction of the model was evaluated using Nagelkerke coefficient. Lastly, Cox and Shell coefficient of determination was used to verify the model (Hosmer and Lemeshow, 2000; Sarhangzadeh et al., 2013).

The goodness fit of the logistic regression model was evaluated using the simultaneous measure of sensitivity (True positives) and specificity (true negatives) for all possible cut off points. The receiver operating characteristic (ROC) curve was drawn and an area under curve (AUC) calculated. AUC of ROC ranges between 0.5 and 1.0 where values closer to 1 indicate better fit.

RESULTS

Factors determining crop raiding

There was a positive association of crop raiding with distance to towns, distance to Kitenden corridor, distance to elephant migration routes, distance to dams, distance to water pans, distance to rocky areas and distance to Kimana small farm holdings. However, the coefficients for ranches, distance to settlements, distance to Kimana conservancies, distance to waterholes, distance to rangers/scout outpost, distance to cultivated land, distance to clay soil, distance to montane forest, distance to woodland, distance to irrigation ponds and distance to Kimana conservancies were negative (Table 1). When an algebraic raster calculation was done, an output map showing levels of crop raiding by elephants emerged (Figure 2).

Table 1: Results of the binary logistic regression model for the factors predicting crop raids by elephants in Amboseli ecosystem

Variable type	Predictor variables	β	S.E	Wald	df	Sig.	Exp (β)
Human related	Distance to settlements	-0.0010592	0.0001045	102.765	1	<0.001	0.999
	Distance to towns	0.0002083	0.0000424	24.131	1	<0.001	1.000
	Distance to scout/rangers outpost	-0.0002383	0.0000317	56.661	1	<0.001	1.000
	Ranches	-0.4908852	0.1201823	16.683	1	<0.001	0.612
	Distance to cultivated fields	-0.0005428	0.0000710	58.471	1	<0.001	0.999
	Distance to Kimana smallholdings	0.0003730	0.0000601	38.509	1	<0.001	1.000
Corridors and routes	Distance to elephant migratory routes	0.0001437	0.0000254	31.886	1	<0.001	1.000
	Distance to Kitenden corridor	0.0001862	0.0000407	20.942	1	<0.001	1.000
Conservation	Distance to conservancies	-0.0001056	0.0000441	5.746	1	0.017	1.000
	Distance to Kimana	-0.0006351	0.0000901	49.709	1	<0.001	0.999

Variable type	Predictor variables	β	S.E	Wald	df	Sig.	Exp (β)
	conservancies						
Vegetation types	Distance to montane forest	-0.0002445	0.0000294	69.238	1	<0.001	1.000
	Distance to woodlands	-0.0005519	0.0001763	9.804	1	0.002	0.999
Soils and Rocks	Distance to rocky (lava) areas	0.0016582	0.0004847	11.705	1	0.001	1.002
	Distance to clay soils	-0.0006024	0.0001649	13.347	1	<0.001	0.999
Water resources	Distance to dams	0.0002814	0.0000428	43.254	1	<0.001	1.000
	Distance to pans	0.0001299	0.0000216	36.064	1	<0.001	1.000
	Distance to waterholes	-0.0002324	0.0000241	92.672	1	<0.001	1.000
	Distance to irrigation ponds	-0.0001514	0.0000287	27.862	1	<0.001	1.000
Model	Constant (Intercept)	-6.1755959	2.0296853	9.258	1	0.002	0.002

Accuracy of the prediction model

The selected model predicted crop raiding levels in the ecosystem significantly based on the Hosmer and Lemeshow test (χ^2=104.865, df=8, $P<0.001$), Nagelkerke (R^2=0.874) and Cox and Snell (R^2=0.656) coefficient of determination. The variables used in the model were separated correctly by an overall value of 94.1% (no crop raid = 92.6%, crop raid = 95.6%). Furthermore, the area under curve (AUC) of the logistic regression model showed a success rate of 98.2%.

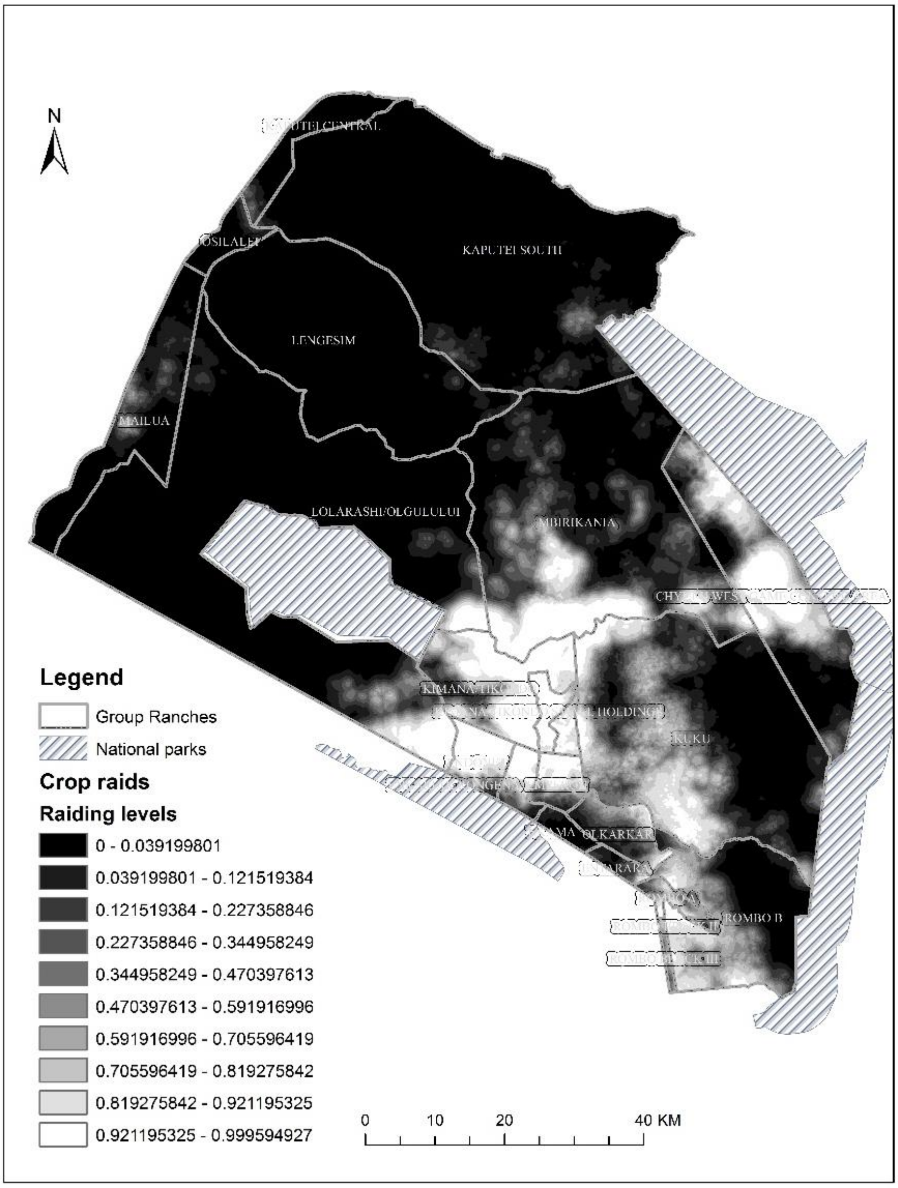

Figure 2: *Crop raiding levels by elephants in Amboseli ecosystem.*

DISCUSSION

Prediction of crop raiding by elephants is usually tricky due to varying environmental variables (Sitati et al., 2003). However, in this study, the distribution of crop raiding by elephants in Amboseli ecosystem were well predicted by our model due to many variables that were considered in the analysis at the smallest unit. Equally, the interpretation of the index map provided can be used to seek for mitigation measures against elephant raiding.

As expected, crop raiding had a negative correlation to distance to human settlements but positive to distances to towns and Kimana small farms holdings. Hence, more crop raiding incidences occurred near settlements (homesteads/manyattas) and this is where cultivation was happening. Settlement in Amboseli ecosystem is more distributed to areas of arable potential and availability of water where crop production can be practiced (Ogutu et al., 2014). These areas include large parts of Kimana and Kuku group ranches which however, happen to be a link between Tsavo West, Chyulu Hills and Amboseli national parks (Kioko et al., 2006; Ogutu et al., 2014). On the other hand, crop raiding occurred away from towns and Kimana small holdings. For towns, this finding can be explained by (i) little or no crop farming being carried out in or near towns and (ii) deterrents of elephants by bright lights, noise by humans and vehicles/motorbikes. Kimana small holdings are pieces of land subdivided and commercialized. This is a more of a town suburb having the effects as a town to elephant distribution. Lots of human activities occur here with most of the areas are electrified which deter elephants at night.

The scouts and rangers outpost correlated negatively with crop raiding by elephants. Ideally, the outposts are usually strategically located based on the threats facing the wildlife in the area including poaching, conflicts and habitat destruction for quick response by scouts or rangers. This, then explains the high crop raiding incidences occurrence. In Transmara, according to Sitati et al. (2003), crop raiding occurred away from KWS outposts. The current location of the outposts had been overtaken by events since elephants no longer utilised those areas due to high human activities.

The negative association of crop raids to ranches shows that certain group ranches experience more crop raids compared to others which can be attributed to availability of water and if the land has been subdivided or leased. These group ranches include Imbirikani, Kimana, Kuku, Olgulului/Ololorashi and Rombo. In Kimana, group ranch, land is fully subdivided which has accelerated cultivation near the wetlands (Okello et al., 2014). According to Kioko et al., (2006), during the dry season, elephants were found to congregate near wetlands. In addition, these group ranches support large numbers of non-migratory species (Okello et al., 2014) elephants included that raid adjacent farms (Fitzgerald, 2013).

Crop raiding incidences were higher on farms located near woodlands, montane forest, all conservancies and conservancies within Kimana area. These are potential elephant refuge during the day and come out at night to raid crops. These results concur with those of Graham et al., (2010) where elephant raiding in Laikipia was negatively dependent to the elephant daytime refuges (large tolerant ranches and forest reserves). Apart from offering refuge to elephants, conservancies, woodlands and forested areas offer pasture (Ogutu et al., 2014) and in some cases security provided by the network of scouts linking the various areas in the ecosystem. During the day, elephants hide on these refuge and attack crops mainly at night and when food crops are ripe (Graham et al., 2009; Pittiglio et al., 2013).

Kitenden corridor and elephant dispersal routes had a positive correlation with crop raiding incidences. Kitenden corridor links Amboseli National Park and Enduimet Wildlife Management area (EWMA) through the Olgulului/Ololorashi group ranch. The intensity of the crop raids were experienced as you move far away from the corridor. Currently, Olgulului group ranch has a management plan and the Kitenden corridor has been set aside for conservation and tourism activities (OOGRMC, 2011). However, at the south east of the corridor, land has been set aside for cultivation which in some occasions the crops grown are raided by elephant. In and around the Kitenden corridor, there is a lease program going on where land owners lease their land for conservation. This has deterred most of farmers from engaging in crop production and thus low cases of crop raids recorded in the area.

Though elephant migratory routes cut through parts of Kimana and Kuku group ranch where most of the cultivation is done, the model predicts that crop raids occur most as you move away from these routes. This is strange as we expected to realize more raids than what the model predicts. Nevertheless, this can be associated to farmers know the wildlife movement route and they employ the necessary deterrents, avoid farming in the route or currently elephants rarely use the routes and when they use they move through it very fast to avoid people (Galanti et al., 2006; Ngene et al., 2010). However, the nearby farms to the known elephant routes get raided. This makes the situation tricky in two ways. One, the routes might have been encroached and land subdivision completed where settlements have been established which accompany fencing and application of other deterrents (Graham et al., 2014). Two, the level of habitat destruction for opening land for cultivation might have left the area unsuitable for use due to removal of stepping stone refuge within the route (Pittiglio et al., 2014). These two might have forced elephants to seek alternative routes.

Another factor that contributed to crop raids was distribution of cultivation. This might look an obvious factor. We do not expect crop raiding by elephants to occur if either crops or elephants miss in the equation. Crop farming that occur in the slopes of mount Kilimanjaro (most rain-fed) experienced crop raiding on the peripheries of the farms while those under irrigation especially in Kimana and Namelok areas were overwhelmed by the elephant raids. This is explained by the fact that lands under irrigation are in small somewhat scattered blocks but those depending on rains are in large blocks (either small scale but linked together to form a huge large continuous block). Graham et al., (2010) noted that small farms surrounded by savanna or elephant refuge places are particularly vulnerable to crop raiding. In addition, Sitati et al., (2003), related spatial crop raiding to the amount of cultivated land where small farms were mostly raided due to insufficient protection. Bearing in mind that these farms under irrigation are situated in historical elephant corridors or dispersal areas (Ogutu et al., 2014), which has even inflated the crop raids.

Water resources have shown mixed relations to the crop raids in the ecosystem. Distances to dams and pans have shown a positive relation to crops raids whereas distances to waterholes and irrigation ponds have shown a negative association. The reason behind is to do with the distribution of these water sources. Dams and pans are meant for livestock and wildlife use and are distributed in the dry lands within the ecosystem. The source of the water is dependent on the rains. No crop farming is being carried out in these areas. On the other hand, waterholes and irrigation ponds occur either close to the irrigation farms (waterholes) or within the farms (irrigation ponds). Most of the crop raids that occur outside the irrigated or rain-fed farms are close to these waterholes. Waterholes accumulate water after rains and can retain the water for some time in the dry season which in turn can be used by wildlife and livestock. Irrigation ponds are water reservoirs collected from a water source to be used in irrigating crops.

Areas containing clay soils had negative correlations to crop raids. Since the ecosystem is an arid area, soils that can retain water to support crop farming are preferred. Though most of the soils in the ecosystem are generally alkaline and saline, soils close to water sources can be extremely fertile (Katampoi et al., 1990; Okello et al., 2014) which supports crop farming. And lastly, crop raids showed a positive correlation to rocky/lava outcrops areas in the landscape. Most of the areas covered by the lava outcrops are not cultivated due to their poor arable potential.

CONCLUSION

The findings of this study have some lessons to be learnt and improvised to help mitigate the crop raids by elephants. This will boost the elephant conservation as well as cushion the local community from the opportunity cost for staying with wildlife. Proper planning may be a blessing but if not done well can be a disaster. Elephant refuge places have shown to be close to cultivations which have led to high concentrations of crop raiding in this regions. For example, Kimana conservancies and Kitenden corridor. The idea to set out these areas for wildlife conservation and livestock grazing is a fantastic idea. However, next to it either cultivation is carried out as planned close to exit point for the case of Kitenden corridor while subdivisions ignited by cultivation potential in Kimana group ranch. All these have led to crop raiding incidents to be high at these areas.

Water is a scarce resource in the region. Flood irrigation as the main crop farming technique in Kimana and Namelok may have worsen the situation escalating the conflict. Wetlands have been source of refuge for wildlife in the dry season, but, these areas have been reclaimed to suit crop farming. Still wildlife will visit these areas to seek water and pasture as their memories guide them. In the process, find water which is not adequate but more palatable pasture (cereal crops) than before. A repeat on this will turn to be a routine attack.

We recommend holistic planning to be undertaken to guide the zonation of the ecosystem into various land uses. Proper sharing and use of water resources to be developed to make sure wildlife, livestock and humans get equitable access to water. Land subdivision has been the main driver of all this challenges. If only land owners can benefit from wildlife, venturing to cultivation may not be a priority. Cultivation is not a sustainable land use in the area because the soils cannot sustain it unless heavy inputs are used which in the other hand may lead to losses. For instance some land owners who refused to join lease programme and opted for cultivation have abandoned farming and since applied to join leases program after the farms productivity declined. Opening up of wildlife corridors or routes should be explored through strategies like payment of ecosystem services and full implementation of group ranch management plans to reduce conflicts.

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INDIGENOUS KNOWLEDGE UTILIZATION AND LAND USE IN TANZANIA: THE CASE OF USAMBARA MOUNTAINS (*A review Paper*)

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ABSTRACT

Utilization of Indigenous Knowledge (IK) in forests is mostly manifested in the local level of forest management, and more used by those who depend directly on forest resources. In the rural area, for a long time people have developed ways to interact with forest for their survival. Ways which created a sense of forest ownership by local people, for supporting their livelihood, and sustained forest needs from one generation to the other. These ways are referred to as IKs and has defined forest people interactions in the rural areas. Unfortunately IK is perceived to lack scientific bound, a weakness that is used by forest scientist and managers to ignore the importane of IK in forest conservation. As a result, local ways of interacting with forest are eroded and washed away. They are not considered significant during forest decisions, hence compromising local people's forest needs and change ownership of the forest from people cantered to conservators cantered. Although scientific, Eurocentric forest conservation aims at attaining sustainable supply of forest services, the rate of forest degradation seems to increase year after year. This called for a need to investigate on decision of forest management with the aim of identifying IK and their relation to forest management. Remote sensing and Geographical Information Systems were applied for land use cover changes assessment, Focus Group Discussion was also used to capture IK. The results reveals existing of forest related IK aspects in eastern Usambara Mountains, however, there is no manifestation of IK utilization in forests. It is recommended to consider utilization of IK in forest for reduced forest degradation and sustained people's livelihoods.

Key words: Indigenous Knowledge, Forest Management, Decision Making

INTRODUCTION

Decisions on who, when, why and how to use resources is what brings uncertainty in forest management. The uncertainty is broadened with many factors including limited information provided to decision makers and sometimes political and economical interference from decision makers. However the case, decision made needs to be reliable and in favour of both of user and nature, without that, the danger of resource wipe up is high. The threat manifests itself with the world ecological footprints[6] versus the ecological capacity. According to Global Footprint Network (GFN), 2012, the world footprints are now 1.5 times earth planet capability to generate the resource we use and absorb the waste. These data alerts the world to making decisions which will ensure sustainable management of resources, because among reasons stated to cause rapid world resource wipe up are policies which do not reflects different local communities ways of living and interaction with the said resource. Tanzania Particularly has a footprint of 1.5 - 2 against its bio capacity of 3. The country's footprints are still positive, however with the ongoing global trade and interaction the country's biocapacity is at great risk, particularly the forest sector Taking example from forest resource depletion rate, only from 1990-2005, about 37.4% of Tanzania forest and woodland habitat have been degraded (MNRT, 2007). There are different factors behind the rate, but also it alarm on the results as reflection of decisions in place. These may be policies, Acts, strategies or institutions in place. Therefore decisions fuels resources management and so need to be significantly put in way that the result balances the bio capacity of the nations and their footprints

Making decisions for forest conservation requires a significant amount of data, which will capacitate forest managers to analyse and integrate these data to overcome the associated uncertainties on forest management. This has led to adoption of new decision support technologies to overcome the problems of data handling, technologies which can quickly and easily collect, store, analyse, retrieve and manipulate data on forest and aid decision making. These technologies are referred to as Geospatial Decision Support Systems (GDSS) see Turban et al., (2001), Bhatta. (2010). Technology has significantly simplified land use change assessment ex situ and therefore easily assessing forest covers change.

Unfortunately, the new technology resulted into spurn of traditional ways of forest management which is used at the local community level. At the community level of forest management, people have been applying their natural knowledge referred to as Indigenous Knowledge (IK) to make forest management decisions and ensure sustainability (Kweka 2004, Africa Adapt., 2011).

The adoption of GDSS has changed many scientist and decision makers thinking towards forests its ability to aid forest decisions came with stereotyping other tools like the IK. Community forest needs are now compromised more than ever and forest sustainability has increasingly being in jeopardy because of stereotype of IK from forest scientists. According to McCall and Minang, (2005) respect of indigenous knowledge is one of the key aspects of good governance and decision making. It is further a positive measure of local community capability, with potential to set community members on an equal status with outsiders experts, and may be the only resources of which the local group, especially the resources poor, has unhindered ownership. Ignoring IK in decision making makes the decisions more of top down, as the technology leaves much to be desired over the activity in question when it comes to implementation of the made decision.

At a large scale forest management GDSS has proven great capability of aiding decision, its validity and reliability is manifested from its capacity to capture, store, analyse, manipulate and retrieve forest data. IK has also been for decades a decision aiding tool in various communities' and has facilitated forest management and sustained peoples forest needs,(Rao & Ramana (2007), Nimachow., *et al* (2010), and Africa Adapt (2011) when forest depletion is increasing and the blame is put at communities adjacent to forest, it shows lack of community ownership of the forest at the same time access to forest resources is limited, there is a need to ensure a use of important IK in forest so as to establish tangible community's participation. Use of GDSS alone to aid decisions on forest accommodates scientific needs for conservation only, and communities' needs from conservation are left compromised. Following this uncertainty a study was conducted in Zigi catchment for the aim of identifying existing IK systems in forests for and link to the land use change in the east Usambara Mountains and suggests ways to best utilize IK for sustainable forest management.

MATERIALS AND METHODS

Study area

The study was conducted in Zigi river catchment which is located within the Eastern Usambara Mountains. It cover an area of about 1050km^2 (Mwasha, 1989,in Mwanyoka, 2005) recent study be Hepelwa (2010) show a size of 1,100 km2, located between 4°48'S and 5° 13' S, and 38°32' to 38°48' E in Muheza, Mkinga and Korogwe districts, Tanga region. It has an elevation of 1,265m and the mean elevation of about 355.44m. The area has a bi – modal rainfall pattern with two rain seasons. The long rain period is March – May and the short rain period is October – December. Monthly average rainfall stood between 30 and 174 mm for the period between 1995 and 2005, On the other hand, the maximum temperature ranges between 28°C and 35°C and the minimum temperature between 17°C and 23°C. Apart from settlement, the area is characterized by six other land use cover and about 15 forest reserves (Figure 1 and 2).

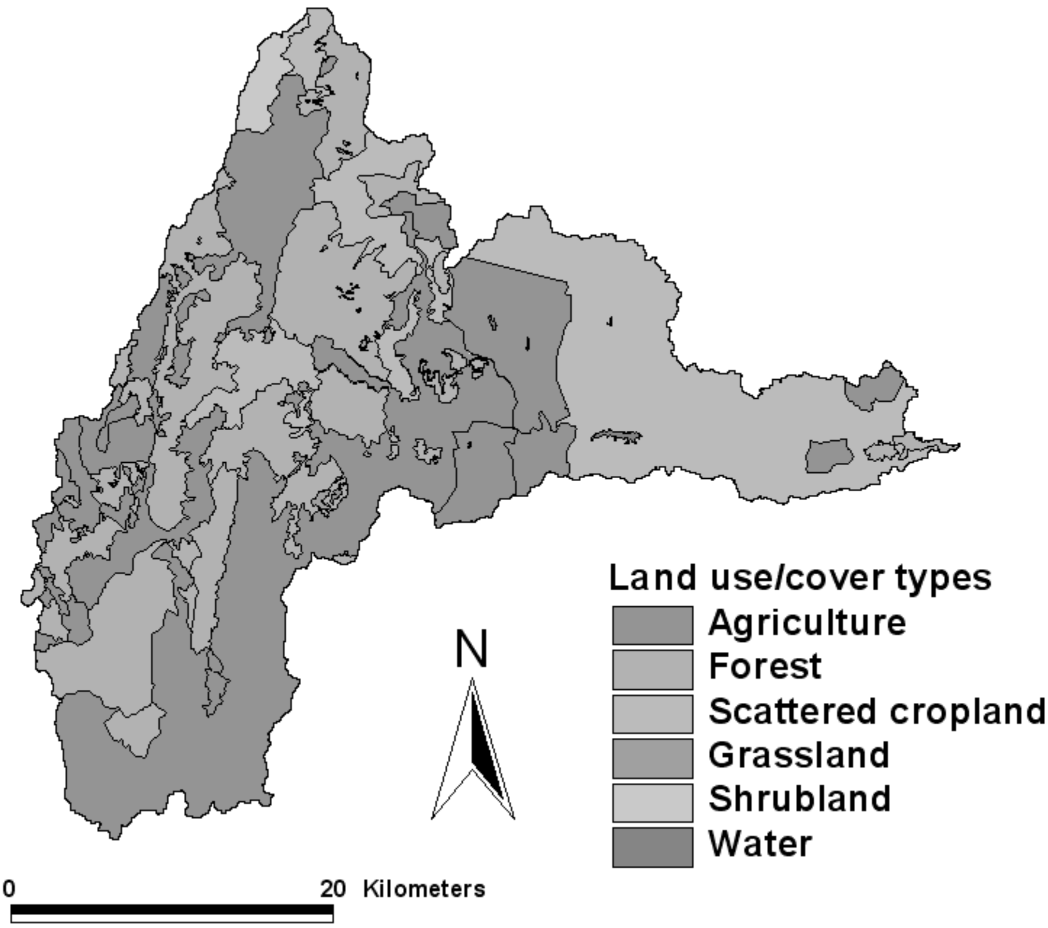

***Figure 11**: Zigi land cover*

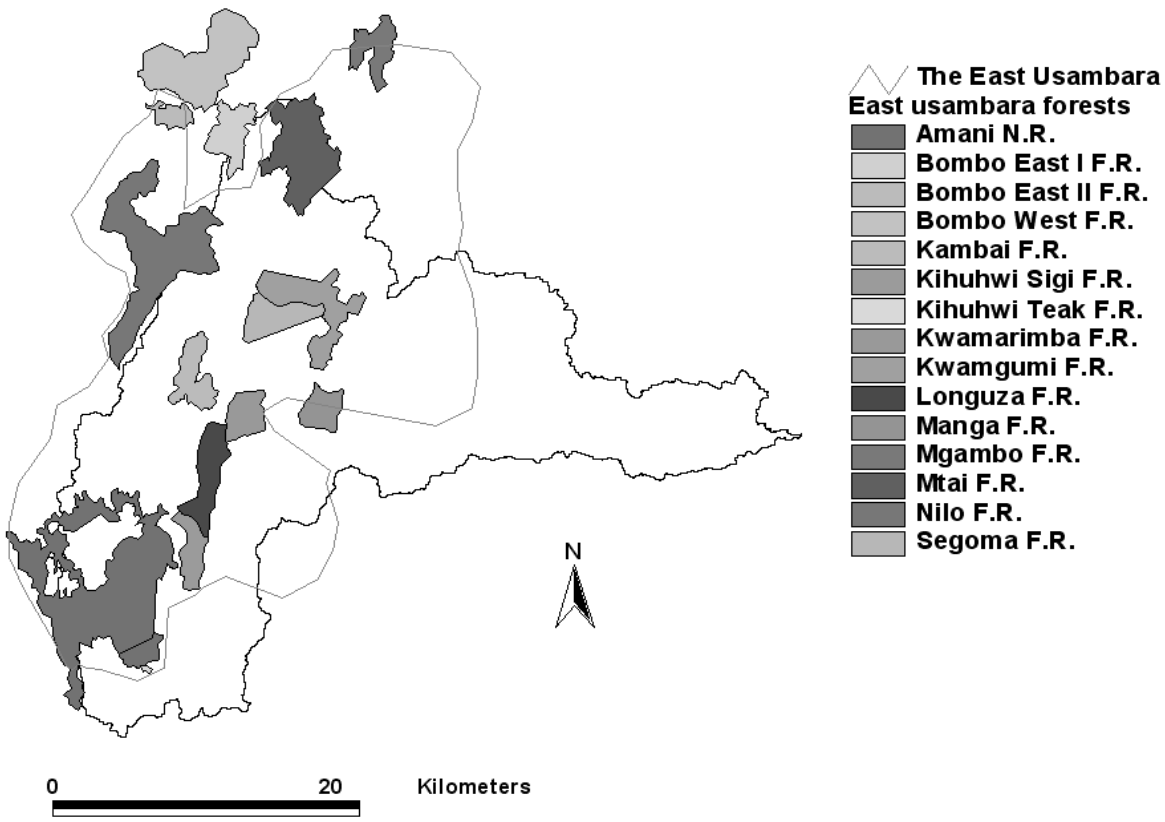

Figure 12: *Forest reserves in Zigi*

The estimated population in the Zigi catchment was about 204,461 in 2012, with 100,843 males and 103,618 females. Household size of 4.3 and a population density of 77 inhabitants/km^2 (NBS, 2012). About 41% and 5.6% of the people are aged below 15 years and above 64 years respectively. The population growth rate is estimated to be 2.2% per annum (NBS, 2012). Agriculture is the main livelihood activity, counting for almost 75%

Focus Group Discussion was used to capture and asses Indigenous Knowledge and practices in relation to forest. IK was also assessed as systems (IKS) that can aid decision on forest management.

The Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) and Content analysis were used to analyse land use cover change and IK respectively. Unsupervised classification and GIS overlay analysis resulted in to land use cover change maps of Zigi Catchment. Spatial data were analysed in panels with an interval of an average of twenty years from 1990 to 2010-14 and related to existing IK for establishing resource and land use change.

RESULTS AND DISCUSSION

Indigenous Knowledge and Forest Management

A better understanding of IK of a community is manifested from community's ways of living and interaction with nature on spatial and temporal basis. In this case the focus is on the forest governance and conservation, it is therefore important to understand the community's interaction with the forests. Communities in Zigi catchment are almost surrounded with forest reserves and nature reserve there are about 14 forest reserves and one nature reserve. The number of protected areas in this area gives a picture of community's forest interaction, that it is stiff and limited. In this area the use of forest resources is for numerous uses including, house construction, wild food, wild/traditional medicine, firewood, worshiping except for few plantations which are entirely business oriented. However because of restrictions other uses like firewood and timber are obtained from household farm trees (Bwagalilo et al, 2013)

The behaviour of community forest interaction differs with altitude; this is because the upstream and downstream communities differ in needs and what the forest offers. This is also influenced by the proximity to forest reserves. Community adjacent to forest reserves have different interaction to those away from forest reserves. However, all communities have their knowledge and signature of forest interaction. There is a significant relation between IK practice and forest management, as provided in table 1.

Table 1: Indigenous Knowledge and Forest Management

Indigenous Practise	Relation to Forest Management
Sacred respect to Kwezitu forest (Which means thick forest) there is believed to be a tree with tits like a nursing women. People are not traditionally allowed to access the forest- the fear limited peoples accessibility to the forest	Some forest remained intact and kept servicing the indirect needs of the people from its natural untouched forest ecosystem
There is Ndola forest considered as sacred forest- only used as tradition place for respect to Gods, no one is allowed to harvest anything from the forest	Some forest remained intact and kept servicing the indirect needs of the people from its natural untouched forest ecosystem
The so called MATUKURU (In	Some forest remained intact and kept

sambaa means a restricted object) people are not allowed to access the forest as it was traditionally used as damping place for one of the twins born after borns, or a kid born illegitimately (without a known father) it was an abomination for Sambaa to have twins or to have a baby with no known father	servicing the indirect needs of the people from its natural untouched forest ecosystem
In Kyala (Sources of Zigi River) no one is allowed to fetch water or bath in that source- it is a real source of the name Zigi, a women Named MZIGI disobeyed the rule and she sank and died, from then on the river was named ZIGI, it is said, in that source sometimes the water erupt like a bomb, it is highly respected to the moment. A lake known as Nanthondu was used to bath infertile women so that they get pregnancy and bear children.	Under the framework of forest and water this prevented catchment damage and allowed forest succession in the catchment because all tributaries were left to distribute water to various parts of the catchment.
Tradition selection of tree species: House construction which depends on forest was very selective to certain types of tree species- some were abandoned eg, Msambia (sispela spp), Mwiza (Brideli micrathesi), Mnawia, some of these were believed to be friendly to snakes	Allowed harvest and utilization of fewer selected species which had a significant interval between one harvest and another. Therefore there was a good forest succession

The Zigi catchment serves in various ways, apart from providing water to Tanga Municipal Inhabitants it also brings vital important to many other people in different ways. For the local population for example the forests often do not have much direct commercial importance, but they are important for the daily subsistence of the people. Forests provide fuel wood, poles, ropes, food, medicines, and household utensils. Apart from these material functions, the local people value the forests for their environmental or religious, (table 1) values (Reyes, 2008). Zigi people do not randomly cut tree for construction of houses. The selection of trees has for long been transferred from generation to generations, for instance, Msambia (*Sispela* spp), Mwiza (*Brideli micrathesi*), Mnawia, some of these were believed and have been scientifically proved to be natural snakes repellants and other are natural mosquito repellants. Traditional houses built from these trees species would last for an average of 50-60 years compared to current houses which would last to 5-10 years only. Agricultural practices also manifest indigenous ways of living and interacting with nature, particularly forest. Types of crops cultivated are those which do not require clearing of forest but needs more forest covers to provide shades and control wind movement. Cardamom (*Elettaria cardamomum*) and black pepper (*Piper nigrum*). All these practices are in one way or another linked to forest health.

Traditional practices like forest worshiping created a distance between people and forest. Like in any other religion beliefs, a sacred place or item is respected by all. The same it is with sacred forests, people do not encroach the sacred forest for the fear of being punished by Gods. Another custom avoided overexploitation of forest resources; it directed people to harvest what they aimed for against harvesting anything found in the forest this also observed by Kweka (2004). It is respected for the fear of disappearing in the forest if doing otherwise. The selection of certain trees species for houses construction also counts significantly in the conservation of forest. The Zigi community people do not just harvest trees randomly but carefully select strong species which would last for 50-60 when used before reconstruction of new houses. This gave a significant succession period for tree species to regenerate and then sustainably harvested by the next generation.

According to EUCAMP, (2002) Reyes, (2008), and Reyes 2009 cultivation of cardamom (*Elettaria cardamomum*) and black pepper (*Piper nigrum*) are among sources of forest deterioration. The main argument being the clearing of the understory which prevents forest succession, have provided a clear explanation of how these crops are linked to forest deterioration. However, the provided scientific explanation does not overrule the fact that temporal aspect of forest deterioration as a result of cultivating cardamom and black pepper is not similar to forest deterioration as a result of commercial logging and establishment of plantations. Evidence shows serious deterioration of forest in the eastern Usambara started in the 1920's to 1980's; it was until 1986 the government of Tanzania started to seriously reinforce logging ban (EUCAMP, 2002, TBA, 2007). It is therefore not only cultivation which causes significant forest deterioration, but it was rather seriously propagated by colonial commercial logging.

Some customs which manifested a direct forest conservation link between community's traditions and interaction with forest is ana example of Lake Nanthondu that was used to treat infertile women. Infertile women were taken to the lake and bath to ask gods to enable them to conceive and bear children. Kyala which is the sources of Zigi River used to be respected and is still respected. These conservation initiatives started before the start of conventional ways of catchment protection. Custom known as "Matukuru" which means restricted thing- this is a name given to a forest which was used as a damping site for twins born and illegitimate children. For these cases therefore, no one could access the forest as it was feared and respected. Sacred forest called Ndola used as a worshiping place, no harvest of any forest resources is allowed from this forest.

The indigenous people have a unique interaction with tree species. Their construction of houses is selective to certain trees species e.g. Msambia (*sispela spp),* Mwiza (*Brideli micrathesi*), which last longer when used for construction than other trees species, further more these tree species are also snakes repellants. Furthermore, various sacred trees were identified including Mvumo (*Ficus sp)*, Mgude (*Sterculia appendiculata)* Mkulwe (*Diospryos mespilformis*), Mshai (*Albizia gumifera*) and Muungu (*Erythrina absyssinica*). They are protected for various uses including medicines, rituals and places where people meet. Anyone cutting a sacred tree is fined a wether or white/black roaster, which was slaughtered to pacify the angered spirits. Some tree species are believed to habour evil spirits (majini) examples of such tree species are Mbuyu (*Adansonia digitata*) and Mgongo, mgude (*Sterculia apendiculata*). Whoever cuts these trees was likely to be affected by these evil spirits. Also trees on top of mountains and in water sources are not cut in the belief that they bring rainfall and conserve water; this is also documented in Kweka, (2004).

Indigenous Practice and Forest Governance

Over two decades ago the world in Rio drew attention to the critical state of the ecosystem on our planet. At the center of the attention and efforts lies the conservation of tropical forest (Rantalla, 2013). It is from that moment redefinition and formulation of forest policies newly began. This, however does not mean there were no any conservation efforts before, there were efforts to conserve forest by strictness' and surveillance. Little consideration was put in the complexities of the socio ecological systems-the interaction between human communities and the forest, and the interdependency between the two. The Tanzania national environmental policy, (1997) clearly states on the importance of harmonious relationship between people and the natural resources for a sustainable development, it is however a question of how this understanding have been taken on board during forest conservation decision making. The Zigi Catchment has 15 forest reserves which is almost 25% of the total land covers of the catchment. Many of these emerged from early 1990's to 2000's; the people of the Zigi Catchment have existed in the area for more than 2000 years (IBR, Nd). For all these years, the indigenous of the Zigi Catchment have learnt to interact with forest for Agriculture, Non Timber Forest Products, Energy; Worshiping etc. all these practices had an extent of conservation to the forest as compared to commercial logging, tea estates and plantations. Sacred forests were respected, medical trees were also respected, not every tree was cut for domestic uses, and catchment areas were too highly respected. Together, they made a positive interaction between the people and the resources. Many policies which came after Rio conference focused on the negative interaction between indigenous and forest. As a result of this indigenous practices/knowledge of forest conservation were left out and new conservation strategies were put forward.

Theoretically, new explicit forest conservation policies and strategies seems nice, however, they little manifest and acknowledge the complex roles of the indigenous interaction with forest resources. Direct benefits accrued from forest by indigenous are now limited by conventional conservation strategies, while the indigenous practice gave access and right to forest resources in an organized implicit ways, convention explicit conservation approaches limits the rights and accessibility. The decision to conserve and establish forest reserves have left aside the complex socio ecological systems existed long ago, consider figure 3: below.

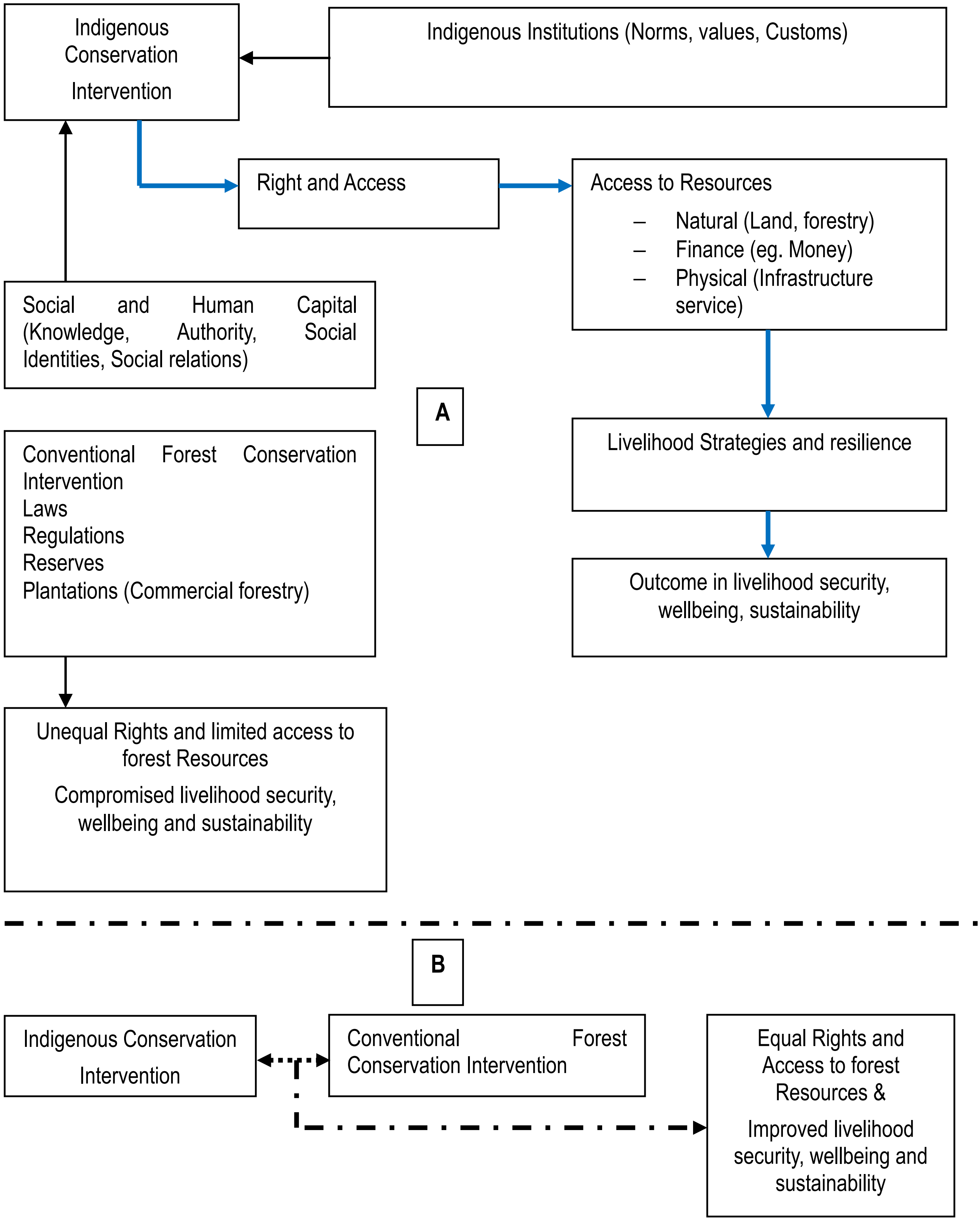

***Figure 13:** Cmplex socio ecological interaction, an indigenous knowledge perspective: Source: Adopted and Modified from Rantalla, 2013*

The interaction between the indigenous and forest have shown a positive relationship in livelihood security and wellbeing as well as sustainability. Their social set up (Norms, Values and Customs) provides rights to resources and well structured access to the forest resources which both defined livelihood strategies and resilience. There is an opposing interaction as shown in part "A" of the figure, limited rights and accessibility to forest resources as caused by conventional forest conservation intervention.

The fact that conventional approaches in forest governance came up to protect the world from turning into a waste land is worldwide appreciated. However, in some areas conventional approaches have either failed at all or compromised livelihood of the indigenous hence resulting to serious conflicting interaction between people and forest. The conflicts arise from the disturbed links between the indigenous and forest resources caused by conventional forest conservation interventions.

Land cover change particularly on forested areas is a result of livelihood activities in many parts of Eastern Usambara. Mostly these livelihoods are reflected from direct local people interaction with forests, the interaction which is termed negative by many conventional conservation approaches. The Gazette of Derema forest to Derema Forest Corridor (DFC) for example, is based on a perceived negative interaction of local people and forests. Scientific research provided a need for biodiversity conservation with no or little considering the local interaction with the resource and their IK. The results are worse on people's livelihoods and sustainability. People's land were taken for conservation hence their prime agricultural livelihood is compromised. Although they were compensated but majority are left with no alternative livelihood, see (MNRT, 2006, Cernea, 2006, Miller, 2013, Mtango and Kijazi, 2014). In this kind of situation the likelihood to people shifting back their dependency on forest is huge. This is one of the examples of decisions to conserve, what about other 14 forest reserves in the area. The million dollar question still remains to be on the level of participation of indigenous and their knowledge's in forest decisions and why the depletion of forest covers is still on the increase. Figure 4 & 5 Presents land use cover change status of the Sigi catchment despite all efforts of conservation in the area

Influence of IK on aiding decisions on forest management

According to Kajembe *et al* (2009) taking firm decisions about future of forest resources, applying it and monitoring the application in a way that it meets the social, economic, ecological, cultural and spiritual needs of presents and future generations of which much of these should be geared towards the local communities surrounding the forest resources is what makes forest management. That means the surrounding communities should be the first hand beneficiaries because they know the resource better than outsiders and therefore have great role to play in the management of the forest resource. The IK often contribute to conservation and the enhancement of biodiversity (Cooper, 2010). For different reasons indigenous communities have felt to be left out of the conservation management process, even though indigenous communities not only live in the forest, but also rely on the forest ecosystem for subsistence.

The existing IK of the Zigi catchment lies on land use since early 1900's. The Eurocentric ways of forest governance have taken place and replaced the traditional ways of forest governance. This is manifested with restricted access imposed by the government to forest resources; communities have lost direct control of their forest resources in the arms of the conventional ways of forest management. With 45.2% of the Zigi catchment land use in protected areas which communities have a limited access and rule over, it is clear that they don't have a room to apply their knowledge in conservation decisions of their forest resources.

Throughout the world there is evidence of IK which have influenced conservation decision. According to Brosius (2005) the Penan hunter gatherer communities in the Malaysian facilitated the land use and managed to push the Government to include their way of living and interests in the plan, see also Osseweiger (2005), Purcell, and Onjoro (2002). Durno *eta al* (2006) have shown how indigenous of pakhasukjai have managed to use their knowledge to restore the natural forest using *Imperata* fallow. All these manifests how important the Ik is in influencing forest conservations.

For the case of the Zigi catchment, despite of a well narration of existence of IK, its influence to forests is almost invisible, this is because almost all protected forest adjacent to the Zigi communities have ignored IK in the planning and conservation of the forest, as a result the forests suffers a serious threat of degradation than it was in the early 1900's. According to Brossius, (2005) the extinction of biological diversity is inextricably linked with the destruction of cultural diversity. With the loss of native cultures, there is also disappearing the vital important knowledge of a way of living in balance with the earth and the value system in which it is encoded. To approach the process of restoration, it is essential to learn to see the earth through native's eyes. This is similar to say that ignoring indigenous knowledge is accelerating the rate of deforestation hence biodiversity loss. There is no clear evidence to establish the ignorance of IK in forest conservation and decision making but the evidence that there were IK applied in forest management and now they are almost eroded leaves much to be desire d as to what happened to the IK. The current forest management initiatives and the proliferation of protected areas peoples are pushed further from the forests and their interaction with forest resources is becoming more controlled with superimposed rules and regulations which have limited or no positive relationship with the indigenous way of living and interaction with forest resources.

The land use of the Zigi Catchment in 1990 gives a picture of communities' interaction with forests; the types of crops cultivated with exception of tea estates had a mutual relationship with forest, cardamom and black pepper requires forest cover to yield better, much more cultivation of perennial crops like cloves also are forest by themselves and a thick forest cover is of advantage to cloves. Although all these were introduced from Europe, the indigenous had for years learned the forest ecosystem and therefore had a better connection. Besides they controlled the forest harvest by technical identification of trees for different purpose. On the other hand tea processing technically requires intense fuel wood use to dry and process. Therefore cleared more forest and allowed people to introduce new cops I the space provided, this is to mean that before introduction of tea estates indigenous had their own sustainable interaction with forest and agriculture, had own technical understanding with forest resource use.

IK and Land Use Cover Change

From early 1990's conservation strategies started in Eastern Usambara Mountains, the efforts resulted to 15 forest reserves. These forest reserves respond to international and national forest policies which call for more forest cover for biodiversity conservation as well as climate change. Table 2, provides land cover change data which uncovers a challenge of the ongoing forest conservation in eastern Usambara Mountains. For two decades, an average of 5614 Ha of woodland has been degraded or converted to other land uses; this is equivalent to 5.3% of woodland loss from 38.8% of woodland in 1990. The data shows a land use with bush land with scattered crop land, with a shrink of 18% from the total 32489 Ha to 13,466 in 20 years. An increase of cultivated land from 18,402 Ha (17.4%) to 35,854 Ha (33.9%), (table 4). Agricultural activities are on the increase and the population growth. Pressure on land use increase hence posing a threat to forest conservation, this is because, local people still direct depends on forest for their survival, therefore, despite reallocating them from forest areas, but still they go back to forest for search of their basic needs. Sustainability of forest conservation lies on secured people's livelihood (Rantalla, 2013). The observed land use cover change tells, how best it would have been, important if the IK could be considered in forests conservation. This could have been resulted into mutual conservation goals between forest and local people community.

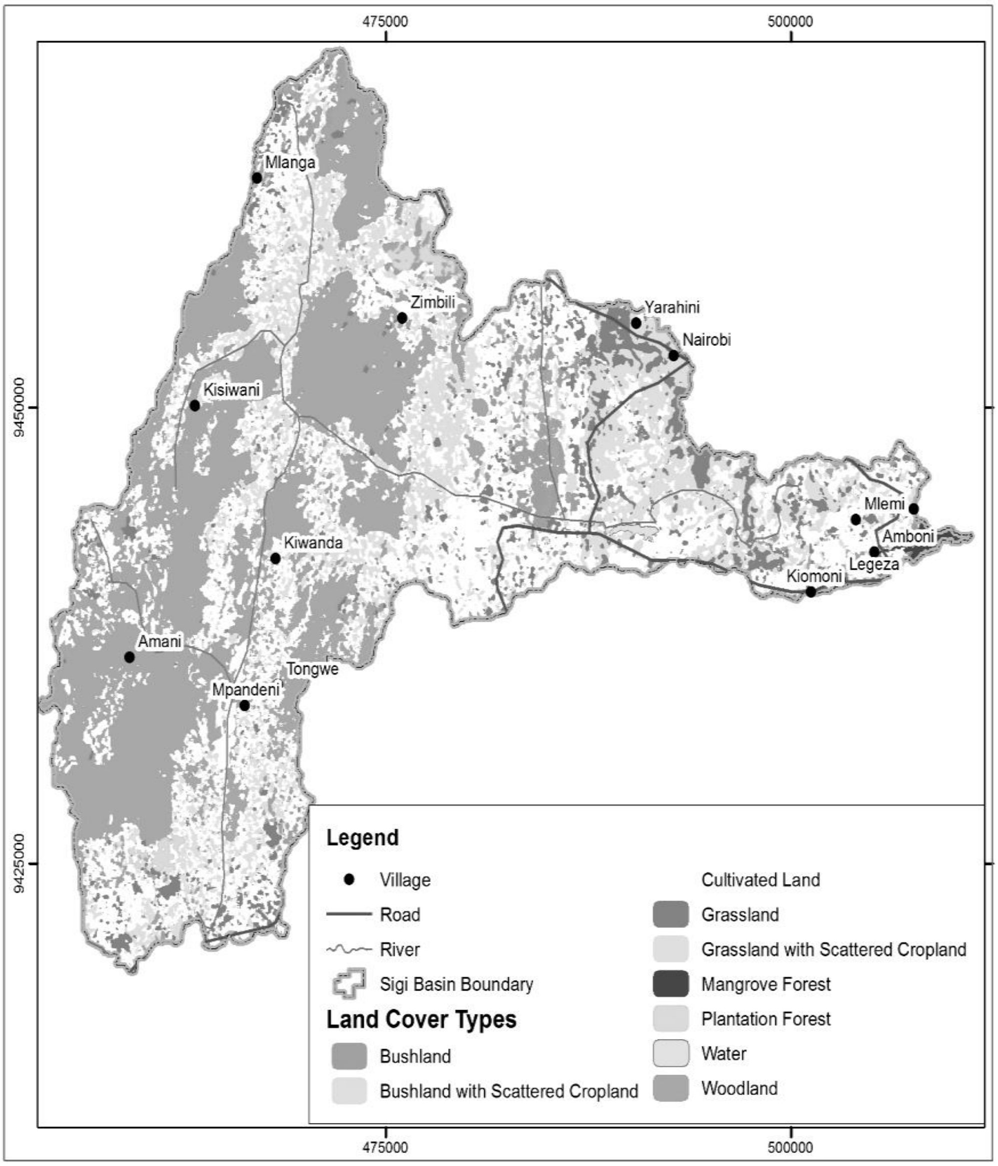

Figure 14: *Land use cover 1990*

Table 2: Land Covers Change in Percentages

Land Use/ Cover Types	Coverage				Land Cover Change	
	Year 1990		Year 2014		1990-2011	
	Ha	%	Ha	%	Ha	%
Bush land	6,283	5.9	4,337	4.1	-1,946	-1.8
Bush land with Scattered Cropland	32,489	30.7	13,466	12.7	-19,023	-18
Cultivated Land	18,402	17.4	35,854	33.9	17,452	16.5
Grassland	430	0.4	6,869	6.5	6,439	6.1
Grassland with Scattered Cropland	6,275	5.9	8,551	8.1	2,276	2.2
Mangrove Forest	145	0.1	385	0.4	240	0.2
Plantation Forest	513	0.5	700	0.7	187	0.2
Settlements			21		21	0
Water	165	0.2	133	0.1	-32	0
Woodland	41,042	38.8	35,428	33.5	-5,614	-5.3
Total	105,744	100	105,744	100		

Source : *Institute of Resources Assesment, 2014*

Table 3: ZIGI BASIN: Budget of the overall change for land cover classes (in Ha), 1990 – 2014

Land Cover	Gain	Loss	Total change (Gain + Loss)	Swap (Total change - (difference of Gain and Loss)	Absolute net change (Total change - Swap)
Bush land	3,963	5182.31	9,145	10,365	-1,220
Bush land with Scattered Cropland	7,749	20714	28,463	41,428	-12,965
Cultivated Land	28,604	9835	38,439	19,669	18,769
Grassland	6,794	284	7,079	569	6,510
Grassland with	6,635	4119	10,754	8,238	2,516

Scattered Cropland					
Mangrove Forest	257	15	271	30	242
Plantation Forest	616	171	786	342	445
Water	132	164.2	296	328	-32
Woodland	35433	14133	49,566	28,265	21,301
Settlements	21	0	21	0	21

***Source:** Institute of Resurces Assesment, 2014*

From a GDSS perspective the area seriously call for conservation measures, because it looks like for various reasons forest degradation is increasing. Among many other reasons to these results is inconsideration of indigenous interest in forest conservation. Use of IKS in forest would have been used together with other conservation approach would have strongly added more values to the management authorities in decisions making plans for forest conservation. Based on the current feeling from local communities that, they have been pushed away from their ancestor's resource they started illegal harvesting of these resources in un-sustainable manner from their own resource, hence the observed degradation and land use- cover changes that are now becoming a big threat.

CONCLUSION AND RECOMMENDATIONS

People's needs and survival appears to be a rubberstamp to conservation decisions. However in many occasions, local people's knowledge on conservation seems to be forgotten in some areas. The current forest conservation schemes that are in place restrict the use and access to forest as well as ownerships to communities around the conserved forests. The stereotype to IK is linked to the continuing forest degradation; and the community had felt that the authorities have grabbed people's rights for forest ownership to conservation and restricted forest uses. Because local people's values, norms, customs and livelihoods still depend on forest, it is challenging. It is therefore important to significantly consider IK in conservation decisions and integrate them to forest conservation schemes. IK is not only needed to be researched on both temporal and spatial basis but also to be treated as decision making aiding tool in sustainable natural resource conservation strategies. IK may lack scientific proofs it is recommended that this local tool should be used in conjunction with other tools to support Management authorities in decision making plans. Currently Geospatial Decision Support Systems (GDSS) counts more on forests conservation, if this will be intergraded IK and it will ensure sustainable forest management plans.

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LIVESTOCK-WILDLIFE CONFLICT IN WEST KILIMANJARO, TANZANIA: STATUS AND ECONOMIC VALUE

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ABSTRACT

Livestock-wildlife conflict is a common phenomenon in areas where humans, livestock and wildlife share the same landscape and compete for limited space and resources. Few studies however, have attempted to calculate the economic value of these losses. We use both qualitative and quantitative methods to assess the status and economic value of these losses in Enduimet Wildlife Management Area in West Kilimanjaro, Tanzania. The findings revealed that while pastoralists experienced direct loss of their livestock through depredation by large carnivores, wildlife sector equally suffered direct cost from retaliatory killings of the carnivores as result of negative attitude towards conservation borne by the pastoralists. Apparently, the loss of livestock to predators represented an estimated cost of around USD 139, 974 for the past five years, whereas the cost of wildlife killed by local communities in retaliation amounted to USD 105,403 in the same period. On the other hand, the hidden costs of the conflict included social unrest among local community members, loss of time used in care and treatment of the casualties, waste of time spent hunting predators and risk of zoonotic diseases such as rabies and brucellosis from wildlife. Overall, the direct and indirect cost of the conflict is enormous suggesting the urgency with which to address the issue in the region. Raising conservation awareness and use of effective preventive measures such as predator-proof fences around livestock penal together with consolation payment and benefit sharing may help in managing the conflict in the area.

Key words*:* Carnivores, economic valuation, livestock depredation, wildlife-human conflict, Enduimet Wildlife Management Area

INTRODUCTION

Human-wildlife conflict has been in existence since human and wildlife started sharing the same landscape and subsequently competing for limited space and resources (Graham et al., 2005; Berger, 2006; Dickman, 2008; Lamarque, 2009).

One form of manifestations of human-wildlife conflict worldwide is livestock depredation (Mazzoli et al., 2002; Ogra and Badola, 2008; Inskip and Zimermann, 2009). Livestock-wildlife-conflict occurs when wildlife requirements encroach on those of livestock populations, with costs both to livestock and to wild animals (IUCN, 2005). In Africa, larger carnivores such as lions, leopards, cheetahs, spotted hyenas and wild dogs are responsible for the majority of livestock-wildlife conflicts (Packer et al., 2005; Kolowski and Holekamp, 2006; Holmern, et al., 2006; Nyahongo, 2007; Ikanda and Packer, 2008; Kissui, 2008). Losses due to depredation are common with livestock such as goats, sheep and cattle (Inskip and Zimmerman, 2009). Their impacts on livestock keeper's livelihood are enormous and even traumatic (FAO, 2009), therefore seen as great threat to livestock-based economy.

Various case studies demonstrate that the conflict can be most challenging for local people living inside or nearby protected areas (Weladji and Tchamba, 2003; Linkie et al., 2007). The conflict is particularly common in protected areas border zone where species that rely on extensive territories get into contact with humans. The border zone serves as population sink i.e. critical zones in which the conflict is the major cause of mortality for both livestock and wildlife (Balme et al., 2009).

Increasing livestock depredation, both in frequency and in severity has been an important concern for livestock producers (Madden, 2004). Studies have revealed that farmers lose as much as three to four animals a month to lion, leopard and hyena predation (Zang and Wang, 2003; FAO 2009). The problem is more intense where livestock holdings are an integral part of rural people's livelihood and income (Ogada et al., 2003; Ceballos and Ehrlich, 2005). Damages by wildlife may have catastrophic economic consequences for hit households as well as critical political and environmental significance for conservation of biodiversity (Butler, 2000).

In areas where hostility is higher and there is a perceived lack of support from authorities, individuals and communities take matters into their own hands including killing and hunting wild animals in retaliatory defense of their livelihoods (Woodroffe and Frank, 2005; Ikanda and Packer, 2008; Kissui, 2008; FAO, 2009; Mariki et al., 2015). As result, several large carnivores are locally extinct due to the conflict (Chardonnet, 2002; WWF SARPO, 2005), leading to poisoning, shooting and trapping of wild animals (Muruthi, 2005; Moss, 2008; Lamarque et al., 2009; Rija 2009). Several factors have been identified to increase the intensity of livestock-wildlife conflict. These factors include human population growth that is associated with an increase in the use of natural resources, expansion of settlements into wilderness areas, land use transformation, species habitat degradation, and loss or habitat fragmentation (Ikanda, 2009). Another factor is livestock population increase that requires large chunks of land, which are increasingly unavailable due to rapid human population growth and increased land use requirements (Ukio, 2010). Lastly is reduced abundance and unfavourable distribution of wild prey and increasing wildlife populations (Shivik et al., 2003; Gubbi, 2012).

There have been several studies in Tanzania on livestock-wildlife conflict (Kikoti, 2000; Muruthi, 2005; Packer *et al*., 2005; Gunn, 2009; Dickman, 2008; Mwakatobe et al., 2013). However, the studies focused on causes for the livestock-wildlife conflict (Kikoti, 2000; Muruthi, 2005; Gunn, 2009; Dickman, 2008; Packer *et al*., 2005) and spatial and temporal patterns of human-wildlife conflict (Rainy and Worden, 2003; Gunn, 2009). Other studies focused on prey preference, location and timing of attacks, and retaliatory killing (Kissui, 2008), and extent of livestock depredation per year per household (Mwakatobe et al., 2013). In this regard, little attention, if any has been directed towards the economic value of losses to both wildlife and livestock.

Elsewhere, few studies of economic value of livestock losses to carnivores have been conducted. For instance, a study by Butler (2000) in Zimbabwe in 1995 showed that predators killed 5% of livestock holdings and the average annual loss per livestock-owning household was US$13, or 12% of each household's net annual income. Correspondingly, a study by Oli et al. (1994) in Nepal showed that snow leopard killed 2.6% to 5.1% of total livestock, representing a quarter of the average per capita income.

This study examined the status and economic value of livestock-wildlife conflict in Enduimet Wildlife Management Area (WMA) in order to propose viable management solutions. Specifically the study compared extent of predation amongst predators, examined trend of the conflict over a five-year period from 2008 to 2012 and assessed economic value of livestock and wildlife loss linked to the conflict. It was hypothesized that the extent of the conflict can lead to negative conservation attitude that may fuel the behaviour of people to retaliate the loss through killing wildlife. Knowledge on economic-burden of livestock-wildlife interaction is important as it may show the degree of the problem. In Enduimet WMA, where human presence and land use is extensive, it is important to link realistic and responsive loss alleviation package in the short term with longer-term measures geared towards greatly minimizing livestock-wildlife conflict.

MATERIALS AND METHODS

Location, background and demographic characteristics of the community in the study villages

Enduimet WMA lies between 2.6352º and 37.4332ºS, and between 3.0776º and 36.6907ºE on the western side of Mount Kilimanjaro in Longido District on the border of Tanzania and Kenya (Fig. 1), and covers 742.275 km^2 combining land from eight villages in Enduimet Division.

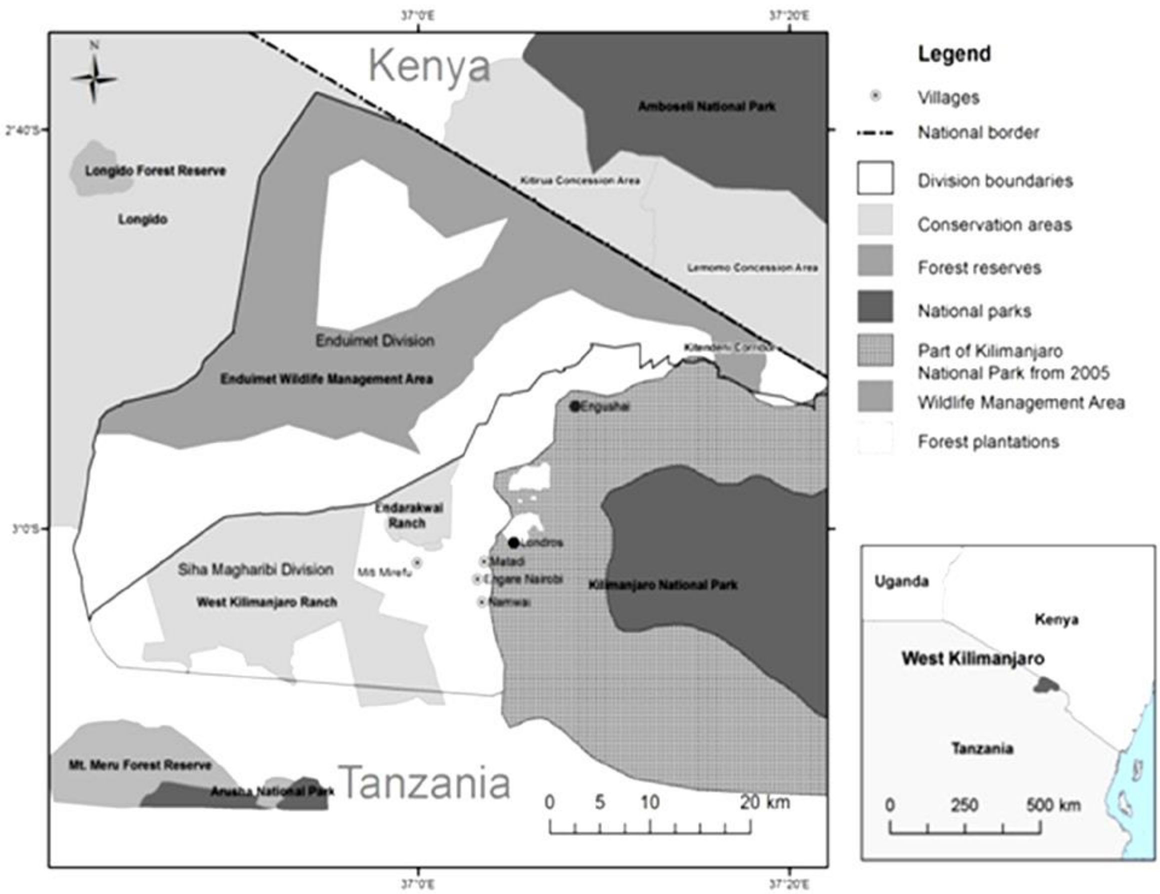

Figure 1: Location of Enduimet Wildlife Management area and surrounding areas (Source: Mariki et al., 2015).

The area constitutes an important trans-national migratory route and dispersal zone for several wildlife populations including elephants (Muruthi and Frohardt, 2006; Madulu et al., 2007; Honey, 2008; Kikoti, 2009; Trench *et al*., 2009). The Wildlife Division earmarked the area for WMA category following an immense wildlife populations decline in 1997 due to bush meat hunting (Nelson, 2007). According to Wildlife Policy of 2007 (MNRT, 2007), a WMA is community-run conservation set up whereby several villages would come together and set aside land for conservation. In return, these villages would receive 25% of the tourism revenues from these areas. The Minister for Natural Resources and Tourism approved the African Wildlife Foundation (AWF) to be the facilitator of the process. Subsequently, in 2004 the Enduimet WMA was established. Based on a Resource Management Zone Plan, in 2007 the Minister for Natural Resources and Tourism (MNRT) declared the organization as an Authorized Association and granted user rights.

Enduiment Division has a population of approximately 17,000 people (NBS, 2002) with the main land use being pastoralism, although the majority of people combine agriculture and livestock keeping. On the other hand, livestock population estimate for the area was at 200,000 animals (NSCA, 2012).

This study covered four villages i.e. Kitendeni, Lerang'wa, Irikaswa and Olmolog villages, which are part of consortium villages constituting the Enduimet WMA. The respondent's population was heterogeneous in terms of age, education and occupation, but with majority being male respondents (Table 1). This was due to that in Maasai tribe, men are household heads, and therefore women are not spokespersons of the household if men are around. Nevertheless, other ethnic groups such as Arusha, Chagga, Pare and Meru occurred on more heavily cultivated lands (Kabiri, 2007).

Table 1: Age, sex and occupation of respondents, and their corresponding frequency and percent frequency

Characteristic	Frequency	Percent frequency
1. Age class		
18-30	47	21.9
31-50	125	58.1
51-90	43	20.0
2. Sex		
Male	177	82.5
Female	38	17.5
3. Occupation		
Pastoralist	10	4.6
Peasant and Pastoralist	170	79.1
Others	35	16.3

Data collection and analysis

This study employed cross-sectional study design whereby two hundred and nineteen (219) respondents from the four villages out of nine villages that form the Enduimet WMA were involved. The villages were purposively selected based on high frequency of cases of livestock predation and retaliation (AWF, 2007). On the other hand, systematic sampling technique using village register book was used to select the households whose household heads or representatives were engaged in the data collection process. Counting started with first serial number household in the register and thereafter every 20th item was automatically included in the sample. About 100 questionnaires i.e. >5 % of total households of the study villages (cf. Boyd *et al.* 1981) were administered to household heads/representatives (25 households in each village). Again, purposive sampling was employed to obtain twenty-four key informants. The group comprised of staff and leaders from the WMA and local government. The distribution was as follows: four staff from African Wildlife Foundation (AWF); four staff from Enduimet WMA; four staff from Longido District Council (District Game Officer, District Livestock Officer, District Forest Officer and District Executive Director). Others were one village elder and one village executive officer of each study village. Since the persons were somehow charged with the responsibility of resolving livestock-wildlife conflict in the area, they were considered a suitable source of information on the subject matter. In addition, we conducted four focus group discussions (FGDs) with about 6-10 people per village (n=35), and Matrix Scoring and Ranking as participatory rural appraisal (PRA) technique with 15 people from each village (n= 60 respondents). The focus group consisted of members of the village environmental and natural resources committee while the PRA exercise involved village members with leadership roles and those without. Experience and knowledge of human-wildlife conflict in the area served as criterion in selecting respondents used during the FGDs and PRA surveys. The idea behind using different survey techniques was to cross check validity of answers (triangulation) obtained during the four separate processes (Kothari, 2004). The data collected throughout included number and type of livestock and wild animals killed; frequency of the killings on a monthly basis; villages in which the incidences occurred and market value of livestock and wildlife killed. We also investigated the hidden costs of the conflict and the overall impact on the peoples' attitude towards wildlife conservation. Furthermore, we reviewed secondary data including reports and studies conducted in the area on human-wildlife conflict to gain more insights on the subject matter. Content analysis involved organizing qualitative data into categories and then grouped into themes. Determination of economic value of the conflict involved computation of livestock value from the sales of livestock from producers to buyers for the past five years after adjusting for inflation (Table 2). On the other hand, computation of wildlife value was achieved using values stipulated in the Wildlife Conservation Act No. 5 of 2009 (Table 2), which have been constant for the past five years (i.e. lion $ 4,900; leopard $ 3,500; and hyena $ 550). Data were organized and summarized into tables in Microsoft Excel 2010. Since respondents were allowed to make multiple answers to a question (multi-responses), percentage of respondents exceeds 100.

Table 2: Real price for livestock and carnivores species calculated from nominal price and consumer price index from 2008 to 2012 (USD 1 = 1, 550 TZS).

Livestock type/Carnivore species	Year	Nominal price (TZS)	Consumer price index	Real price (TZS)
Cattle	2008	410 000	190.1	215 562
	2009	450 000	173.3	259 665
	2010	480 000	162.5	295 384
	2011	520 000	150	346 666
	2012	780 000	100	780 000
Goats	2008	46 000	176.1	26 121
	2009	50 000	162	30 864
	2010	60 000	135	44 444
	2011	72 000	112.5	64 000
	2012	81 000	100	81 000
Sheep	2008	34 000	202.9	16 757
	2009	45 000	153.3	29 354
	2010	53 000	130.2	40 706
	2011	60 000	115	52 173
	2012	69 000	100	69 000
Donkey	2008	27 000	244.4	11 047
	2009	31 000	212.9	14 560
	2010	46 000	143.5	32 055
	2011	55 000	120	45 833
	2012	66 000	100	66 000
Lions	2008	7 595 000	100	7 595 000
	2009	7 595 000	100	7 595 000
	2010	7 595 000	100	7 595 000
	2011	7 595 000	100	7 595 000
	2012	7 595 000	100	7 595 000
Hyena	2008	852 500	100	852 500
	2009	852 500	100	852 500
	2010	852 500	100	852 500
	2011	852 500	100	852 500
	2012	852 500	100	852 500
Leopard	2008	5 425 000	100	5 425 000
	2009	5 425 000	100	5 425 000
	2010	5 425 000	100	5 425 000

Livestock type/Carnivore species	Year	Nominal price (TZS)	Consumer price index	Real price (TZS)
	2011	5 425 000	100	5 425 000
	2012	5 425 000	100	5 425 000

RESULTS AND DISCUSSION

Predator species

Four carnivore species i.e. spotted hyena *Crocuta crocuta),* lion *Panthera leo,* leopard *Panthera pardus* and black-backed jackal *Canis mesomelas*, and one primate species i.e. olive baboon *Papio anubis* emerged as the main drivers of the conflict with dissimilar effect among villages. For instance, all respondents in Lerang'wa and Olmolog villages condemned *Crocuta crocuta* as the most bothersome livestock predator. On the contrary, all respondents in Kitendeni village pointed their fingers at *Panthera leo*. However, *Canis mesomelas* and *Papio Anubis* posed least threat to livestock and crops respectively in all villages while threat by *Panthera pardus* was close to intermediate (Table 3).

Table 3: Proportion of responses on problem animals known to attack livestock in various villages in the Enduimet Wildlife Management Area in West Kilimanjaro

Predator	Village			
	Lerang'wa	**Irikaswa**	**Kitendeni**	**Olmolog**
Leopard	5(20)	4(16)	4(16)	5(20)
Hyena	**25(100)**	5(20)	6(24)	**25(100)**
Lion	6(24)	6(24)	**25 (100)**	4(16)
Jackal	4(16)	2(8)	4(16)	2(80
Olive Baboon	0(0)	0(0)	4(16)	0(0)

The number outside parenthesis refers to the number of respondents whereas the number in the parenthesis refers to percent response (n=100).

Since there was no census records of carnivores and knowledge on predator preference to livestock for the area, it was not clear why *Crocuta crocuta* was more notorious in the two villages and *Panthera leo* in the other despite all villages being in the same ecosystem. However, Mishra et al. (2001) established that predator density, individual predator behavior, natural prey population and predator-prey interaction were important in determining the frequency or extent of attacks of livestock by wild carnivores. Observation by respondents about the tendency of leopard to kill several sheep and goats at a go once in a livestock pen is in agreement with observations by Srivastav (1997) in India and Tamang and Baral (2008) in Bardia National Park, Nepal.

Trend and magnitude of livestock-wildlife conflict

Livestock depredation from 2008 to 2012

Out of 2,299 livestock attacked, 2,262 died and only 47 survived injuries. On average, carnivores killed 92 goats, 11 sheep, 10 cattle, and 1 donkey per year per village, suggesting that goats were the most and donkeys the least killed. Overall, the pattern and trend in livestock depredation was divergent among villages. For example, Olmolog and Kitendeni villages demonstrated a strong and steady increase in goat depredation from year 2008; however, in Olmolog it reached peak in 2010, after which there was a progressive decline to 2012. Contrary, goat depredation pattern for Kitendeni consisted of double peaks i.e. in 2010 and in 2012 (Table 4). Olmolog also experienced relatively higher sheep depredation in 2010, but with decline towards 2012 while killing of cattle and donkey in the five-year period was relatively negligible (Table 4). In this case, the total number of cattle and donkey killed in the village was equivalent to approximately 5% and 1% of total number of goats killed in the same village respectively. However, the number of cattle killed in Kitendeni for years 2009, 2010 and 2011 was on the same scale, but relatively lower in 2008 (Table 4). The increasing trend of goat and cattle killings in this village could be associated with its proximity to Kitendeni Wildlife Corridor that connects protected areas such as Kilimanjaro National Park, Longido Game Controlled area, Enduimet WMA in Tanzania, and Amboseli National Park in Kenya. The village location is seemingly prone to predators that disperse out of the corridor and attack livestock. A number of studies such as Shemwetta and Kideghesho (2000), Nyhus et al. (2003), Naughton-Treves et al. (2004) and Mwakatobe (2013) so far have accredited that communities close to wildlife protected areas usually suffer great impacts caused by carnivores. Conversely, the declining trend of goat and sheep killing for Olmolog after 2011 could be due to the villagers' efforts to construct predator-proof bomas (stockades) thus increased safety to the small stocks from hyena and lion attacks. Studies of Mwakatobe et al. (2003) and Muruthi (2005) in Tanzania, and Ogada et al. (2003) in Kenya also reported that despite intense perceived conflict with carnivores, predator-proof boma play great role in reducing livestock depredation.

Contrary, in 2008 and 2009 relatively fewer incidences of livestock depredation prevailed in Lerang'wa village for all types of livestock (Table 4). There were also zero depredations on donkey along with low number of killed sheep and cattle in the five-year period except for goat depredation, which increased in 2010 and peaked in 2011 (Table 4). Such trend constituted evidence for the overall low incidences of livestock depredation in the village. The observed increase in goat depredation in the two successive years could be associated to seasonal rainfall changes (Patterson et al., 2004), which limited natural prey availability. On the other hand, the overall reduced number of killing in 2012 was probably due to increased alertness in guiding livestock especially during the night. Most communities in East Africa, use simple weapons like spears, knifes, cowbells, tins, stones, dogs or firearms to protect livestock from carnivore attack (Ogada et al., 2003; Patterson et al., 2004; Mariki et al., 2015). Guarding is also a popular preventative strategy in some parts of India, where majority of farmers ranked guarding as the most efficient and common measure to protect their crops, despite requiring additional labor (Sekhar, 1998).

In Irikaswa village, trend of goat killing increased steadily and reached its peak in year 2011 after which it dropped (Table 4). Apparently, the total number of other livestock preyed on during the five-year period was less than half the number of goats killed (40.5%) in 2011. The number of cattle killed in the village rose slightly only in 2010, but that of donkey remained very low throughout the five-year period hence constituting 1.2% and 4% of goat and sheep killed in the village respectively in the five-year period.

According to respondents, livestock depredation is attributable to at least three reasons: - proximity of villages to wildlife habitats (55%), less wild prey during dry season (37.9%) and less control of problem wildlife by conservation authorities (7.1%). We are in favour of the first two respondents' opinions, as they sound more credible considering findings from studies elsewhere. For example, Patterson et al. (2004) reported intense carnivore threats for Kenyan livestock ranches neighboring Tsavo National Park as result of settlement expansion into and around the protected area due to human population growth, which increase the chances of wildlife attack to livestock. Human population growth also confine wildlife species into marginal habitat patches thus competing with local communities (Tamang and Baral 2008; Jacobsen and Hanley, 2009; Pettiqrew et al., 2012). On the other hand, during dry season, the area experiences mass emigration of native ungulates in search of forage elsewhere, which leaves the non-migratory predators hungry (Karani, 1994). The subsequent scarcity of prey seemingly causes predators to shift their dietary requirements to livestock (Patterson et al., 2004).

Table 4: Number of livestock preyed on by wild carnivores in Lerang'wa, Irikaswa, Kitendeni and Olmolog villages from 2008 to 2012

Village	Livestock type	Number of livestock preyed on each year					Total
		2008	2009	2010	2011	2012	
Lerang'wa	Cattle	0	8	22	7	6	43
Irikaswa		0	1	3	2	2	8
Kitendeni		6	**32**	**25**	**22**	12	97
Olmolog		3	13	9	12	7	44
Lerang'wa	Goat	15	12	140	214	124	505
Irikaswa		3	10	13	**34**	24	84
Kitendeni		**9**	**21**	**95**	**80**	**161**	**366**
Olmolog		**72**	**110**	**372**	**210**	**127**	**891**
Lerang'wa	Sheep	1	5	11	3	0	20
Irikaswa		2	0	6	7	10	25
Kitendeni		0	0	8	1	4	13
Olmolog		52	15	**67**	14	13	161
Lerang'wa	Donkey	0	0	0	0	0	0
Irikaswa		0	0	0	1	0	1
Kitendeni		0	0	0	0	0	0
Olmolog		1	0	2	1	0	4

Lions mostly attacked cows, while hyenas and leopards attacked goats and sheep. However, we associated the high number of goats killed to their ubiquity compared to other type of livestock, and the small body size that increases their proneness to attack than other livestock species. Studies in Kenya (Ogada et al. 2003) and Pakistan (Kabir and Ghoddousi 2014) found similar results. In addition, respondents lamented that although leopard does not seem to be as important as hyena and lion in terms of overall depredation, the species is disreputable for breaking into livestock pens and killing large number of sheep and goats at one time.

Wildlife persecution from 2008 to 2012

In Kidendeni and Lerang'wa villages, fifteen and eight predators respectively were killed (Table 5) with none in Olmolog and Irikaswa villages. In both villages, persecution of *Panthera leo* occurred throughout the five-year period making the species the most killed compared to the other two. In Kitendeni, two lions were killed annually and the highest persecution occurred in 2011 (Table 5). Other carnivore species killed in retaliation to livestock depredation were *Crocuta crocuta* and *Panthera pardus*. However, there was no leopard persecution in Lerang'wa village. Sillero-Zubiri and Laurenson (2001) also found similar hostility towards carnivores.

Table 5: Type and number of predators killed in Kitendeni and Lerang'wa villages from 2008 to 2012.

Village name	Carnivore species	2008	2009	2010	2011	2012
Kitendeni	Lion	2	2	1	3	2
	Hyena	2	0	0	1	0
	Leopard	1	0	0	1	0
Lerang'wa	Lion	1	1	1	2	2
	Hyena	0	0	1	0	0
	Leopard	0	0	0	0	0
Total number of carnivores killed for Kitendeni village=15						
Total number of carnivores killed for Lerang'wa villages=8						

Absence of retaliatory killings of wildlife in Olmolog and Irikaswa villages was associated with provision of conservation education with emphasis on the need to live in harmony with wildlife in their villages. As a result, the villagers developed good attitude towards conservation hence livestock depredation was not a driving force of hostility towards large carnivores. This suggests that factors such as insufficient awareness on conservation need may additionally influence the retaliatory killing behaviour of carnivores. Wagner et al. (1997), Dickman (2008) and Knight (2000) also acknowledged that conservation awareness campaigns are important in shaping peoples' views and attitudes towards what seems to be hostile wild animals.

Season, location and time of predator attack and retaliation attitude

Majority of respondents i.e. 67.2% (all villages pooled together) stated that attacks were more intense in the dry season (from August to October) while 30.8% of respondents felt that attacks were constant in both wet and dry seasons. The former is likely because most often, in dry season prey animals become scarce, a situation that compels carnivores to turn to livestock as an alternative (Saberwal et al., 1994; Ramakrishnan et al., 1999). Nevertheless, 2% of respondents considered wet season to be a period of more frequent attacks. Negatively affected respondents from Lerang'wa and Kitendeni villages expressed their desire to continue retaliatory killings of carnivores in response to their lost livestock and sleepless nights on guard against predator attacks to their livestock. In addition, they wished large carnivores decline in number or disappear entirely from the ecosystem. Related studies by Forder (2006), Kushnir (2010) and Marchini (2010) described similar negative attitude and added that perception of carnivores' impacts on human lives and livestock is likely to lead to negative attitude towards conservation of wildlife.

There was discrepancy among respondents regarding time and location of livestock attack by predators. Majority of respondents (61%) reported that attacks occurred inside bomas and they took place at night when livestock are in thorn stockades. This observation is similar to reports by Butler (2000), FAO (2009), Ikanda (2009), Ogada et al. (2003) and Packer et al. (2005). Nevertheless, the remainder of respondents (39%) insisted that wild predators have no specific time and area of attack, meaning that they attack both inside and outside bomas during both day and night, so long they get opportunity to do so. The latter opinion did not exclude attack during daytime when livestock are grazing. This argument corresponds to that of Patterson et al. (2004). It was also reported that livestock bomas ≤ to 1.5 m high were more prone to attack by predators since lion and hyena would simply jump over and reach livestock.

Economic value of the livestock-wildlife conflict

Losses of livestock to predators represented an estimated cost of TShs. 216,959,878 (USD 139, 974) for the past five years (Table 6). However, loss of wildlife killed by local communities as a revenge for their lost livestock for the past five years amounted to TShs. 163, 375,000 (USD 105,403;Table 6) this being less than the livestock cost by 24.7% (USD 53,584,878).

Table 6: Number of livestock and wildlife predators killed, and their real price from 2008 to 2012

Year	Livestock			Wildlife		
	Type	Number	Value (TShs)	Type	Number	Value (TShs)
2008	Cattle	9	1,940,058	Lion	3	22,785,000
	Goat	99	2,585,979	Hyena	2	1,705,000
	Sheep	55	921,635	Leopard	1	5,425,000
	Donkey	1	11,047			
Sub-total		**164**	**5,458,719**		**6**	**29,915,000**
2009	Cattle	54	14,021,910	Lion	3	22,785,000
	Goat	153	4,722,192	Hyena	-	-
	Sheep	10	293,540	Leopard	-	-
	Donkey	-	-			
Sub-total		**217**	**19,037,642**		**3**	**22,785,000**
2010	Cattle	59	17,427,656	Lion	2	15,190,000
	Goat	620	27,555,280	Hyena	1	852,500
	Sheep	92	3,744,952	Leopard	-	-
	Donkey	-	-			
Total		**771**	**48,727,888**		**3**	**16,042,500**
2011	Cattle	43	14,906,638	Lion	5	37,975,000
	Goat	1076	68,864,000	Hyena	1	852,500
	Sheep	25	1,304,325	Leopard	1	5,425,000
	Donkey	2	91,666			
Sub-total		**1146**	**85,166,629**		**7**	**44,252,500**
2012	Cattle	27	21,060,000	Lion	4	30, 380,000
	Goat	436	35,316,000	Hyena	-	-
	Sheep	27	1,863,000	Leopard	-	-
	Donkey	5	330,000			
Sub-total		**495**	**58,569,000**		**4**	**30, 380,000**
Grand Total		**2,793**	**216,959,878**		**23**	**163, 375,000**
Summary	**livestock type**	**Number**	**Total value per livestock type killed from 2008 to 2012 (TShs)**	**Carnivore species**	**Number**	**Total value per carnivore species killed from 2008 to 2012 (TShs)**
	Cattle	**192**	**69, 356, 262**	**Lion**	**17**	**133, 925, 000**
	Goat	**2384**	**139, 043, 451**	**Hyena**	**4**	**3, 410, 000**
	Sheep	**209**	**8, 127, 452**	**Leopard**	**2**	**10, 850, 000**
	Donkey	**8**	**432 713**			

These results suggest that the loss of livestock to wildlife predators is higher in economic terms as compared to the wildlife lost through retaliation by the local communities. These results are similar to those observed by Asheim and Mysterud (2004), Tamang and Baral (2008), and Nyahongo and Røskaft (2011) who reported that people's financial loss of livestock to predators outweighs loss of predators to human killings as part of their revenge during retaliation. Amount of livestock lost has big economic impact on rural communities (Hazzah, 2006; Ikanda, 2009; Tsewang *et al.,* 2007) whereby loss of single domestic animal to wildlife may create serious socio-economic perturbations on affected families because livestock act as social capital particularly in pastoral societies, and a sign of wealth in most rural communities.

Benefits versus costs

Majority of respondents (86%) felt that wildlife conservation is of relatively less benefits to local community. They complained that conservationists and wildlife authorities do not pay attention to their concerns about losses of their livestock and the associated hidden costs such as sleepless nights, time and energy embodied in activities related to security of their livestock as far as attack by wildlife is concerned. They also wished there were practically accessible consolation scheme. They described the current consolation scheme as dummy, bureaucratic, inaccessible, and politically designed to deceive local community. However, 34% of respondents felt that in spite of all the losses they encounter from wildlife, they still realize some benefits from wildlife conservation. Benefits include employment opportunities, support of school fees to children belonging to families that cannot afford, and social services such as water, some medical care through dispensaries and education through primary and secondary schools. This implies that segments of local community today appreciate wildlife and want to continue to co-exist with wildlife as long as they realize some benefits in one way or another.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Conservation of large and potentially dangerous wildlife carries a definite economic cost to humans in terms of loss to their livestock and other costs related to livestock depredation. This cost is borne disproportionately to human community neighbouring wildlife habitats. While it is vital to counterbalance these costs due to damage inflicted by wildlife upon human communities, it is also important to recognize the human impacts on wildlife and their habitats.

In Enduimet WMA, where human presence and land use is extensive, it is critically important to come up with a realistic long–term and responsive loss alleviation packages along with longer-term measures geared towards keeping livestock-wildlife conflict at minimal level. The traditional culture of tolerance against losses to wildlife has significantly contributed to the higher level of tolerance to economic losses, but that cannot continue indefinitely. As finances have begun to cover cultural symbolism in this era of demand and supply of goods and services, conservationists, scientists and politicians must recognize this reality in conserving wildlife.

RECOMMENDATIONS

i. Awareness raising can be an effective means of managing the livestock-wildlife conflict if carried out starting with grass root (primary school), then pastoralists community through the traditional authority of headmen, and finally advanced to higher educational and professional levels.
ii. Educating rural villagers in practical skills such as construction of predator proof bomas would help them acquire and develop new tools for defending their livestock.
iii. Consolation scheme for affected households along with the current revenue sharing by villages forming the WMA would help fostering further positive attitudes towards wildlife and encourage local populations to support conservation.
iv. Where alternative land and incentives are available, the government relocation of local communities to areas offering better access to natural resources and improved socio-economic opportunities can offer an adequate solution to managing livestock-wildlife conflict.

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ASSESSMENT OF LIVESTOCK LOSS DUE TO SPOTTED HYENAS IN SELECTED VILLAGES OF RORYA DISTRICT, TANZANIA

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ABSTRACT

The aim of this study was to assess livestock losses due to depredation by spotted hyenas (Crocuta crocuta) in three villages, Chereche, Kowak and Omuga, in Rorya District, Tanzania. Data were collected in these villages using standardised questionnaire and interviews involving 194 respondents from households that claimed to be affected by hyenas. The data was stored electronically and analysed using Statistical Packages for Social Sciences (SPSS). We tested predictions derived from two hypotheses based on factors likely to influenced livestock predation. These were that: 1) livestock predation should decline as the foraging distance of hyenas from the Rorya hills (where hyenas were thought to chiefly den) to study villages increased; and 2) livestock predation should increase with the total number of livestock within each study village, as reported by a census in 2013. Results revealed that sheep were claimed to be the main livestock species attacked by hyena, followed by goats. Cattle were rarely attacked. Results of our statistical analysis of attacks on sheep did not support the predictions of either hypotheses. Hence the reported extent of hyena attacks on sheep was not significantly influenced by the foraging distance of hyenas from Rorya Hills, or by the number of livestock held in a village. In line with previous studies, our results indicate that disease caused significantly higher loses of cattle than hyena depredation, however losses of goats to disease and predation were similar and losses of sheep to disease where lower than loss due to predation. We consider that the high number of livestock per village and the disposal of household waste and offal in the field by household, combined with lack of predator proof bomas may all contribute to the relatively high predation of small livestock in study villages. Results of our study suggest that four measures would reduce livestock depredation in study villages: 1) The construction of predator proof bomas; 2) a significant reduction in the disposal of household waste in field close to villages;

and 3) a reduction in bushmeat hunting to increase wild ungulate prey for wild carnivores. Moreover, improved veterinary services to reduce livestock losses to disease would increase meat production and the income of farmer.

Key words: Livestock loss, spotted hyena, Rorya District

INTRODUCTION

Human-wildlife conflicts have occurred since time immemorial. Livestock predation is one key cause of conflict but often the level of livestock depredation claimed by farmers in many countries is often exaggerated to attract public attention and/or to mask the effect of poor livestock management (Infield, 1996; Nabane, 1996; Nyahongo *et al.,* 2007). This negative attitude of farmers towards carnivores is a challenging issue to both wildlife conservation and rural development (Woodroffe, 2000). In sub-Saharan Africa, human population growth is relatively high. As a result, there is an increasing demand for land and natural resources utilization that leads to degradation and fragmentation of natural habitats. Habitat degradation and fragmentation often result in decline in biodiversity (Holzapfel, 2007). Large carnivores, at the top of the food-chain are particularly affected by expanding human populations, as they typically require large territories that hold sufficient prey to sustain them outside protected areas, and hence their territories often encompass farmland and villages (Daszak *et al.,* 2001).

The natural prey species of large carnivores are often targeted by bushmeat hunters and this can result in a significant reduction in the density of natural prey species in carnivore territories outside protected areas (Kaltenborn *et al*., 2005; Nyahongo *et al.,* 2005). Under these circumstances, carnivores can be expected to either increase the size of their territory, with the result that they will occur at lower densities than in natural habitats and/or alter their diet to include items that they would not consume in natural habitats, such as livestock and human refuse (Osborn and Plumpter, 2002). The densities at which carnivores persist in human altered habitats will therefore mainly be determined by the availability of natural prey species, domestic stock and other forms of food resources, such as human refuse. In many areas of Europe, carnivores such as the red fox *Vulpes vulpes*, are often accused of killing lambs during the lambing period, but many lambs eaten by foxes are those that are still born or die of other causes (such as inclement weather) before being scavenged by foxes (Holzapfel, 2007). Thus, domestic stock and human refuse may provide an important component of a wild carnivore's diet without necessarily being responsible for increasing livestock predation especially when refuse is disposed of in a manner that allow wildlife to utilize it as a food source. For example, offal from slaughtered animals and discarded household food can provide carnivores with a valuable food source. In some human cultures, carnivores as well as scavenging birds such as vultures are used to dispose offal, refuse and even human bodies (Patterson *et al*., 2004). In these cultures, these items are taken to a particular site, away from human habitation for disposal by carnivores. When refuse is not disposed of in this manner, refuse that accumulates around human habitations will inevitably attract carnivores that may then present a threat to livestock and other domestic animals, such as dogs (Kolowski and Holekamp, 2007).

In northern Tanzania, and rural areas surrounding the western side of the Serengeti National Park, the human population is growing at approximately 4% (Loibooki *et al.*, 2002). The development of infrastructure such as all-weather roads promotes the generation of incomes in rural areas, as does bushmeat hunting and the production of cash crops and livestock. Farmers with large herds of livestock are relatively wealthy members of the communities (Loibooki *et al*., 2002) and as a result the loss of a few animals due to predation is not equivalent to the economic burden caused by a similar loss to a farmer with only a small livestock herd. Livestock losses due to causes such as disease or straying animals might be expected to provide more food for carnivores in areas where farmers have larger herds than in areas where farmers only have few livestock (Mwakatobe *et al.,* 2013). However, more wealthy farmers may invest more in veterinary services thus the number of animals they lose to disease may be low. Furthermore, wealthy farmers may invest more in constructing more robust night holding facilities (bomas) for their herds that are more predator-proof than those constructed by less wealthy farmers (Thompson *et al*., 2010). Thus various factors might influence how much food carnivores obtain from livestock through both scavenging and predation.

The disposal of human refuse is a growing problem in many countries (Holzapfel, 2007). The use of open rubbish-dumps typically at some distance from towns, are known to attract wildlife that scavenge on food remains. However, in many African villages and towns, the disposal of household rubbish is not organised by a local authority, and individual households are responsible for disposing off their waste (Marit *et al.*, 2012). As a result, a considerable amount of food is discarded within villages and towns, which attracts wildlife that utilises this food source. Wildlife therefore can be helpful in waste disposal – but conflict between humans and wildlife is often inevitable when refuse is disposed off close to houses (Rasmussen, 1999).

Quantification of livestock loses to the west of the Serengeti National Park revealed that disease is the leading loss factor (Nyahongo *et al.* 2005; Nyahongo and Røskaft, 2012) Farmers consider the presence of carnivores to be incompatible with livestock husbandry because a single incident of predation on a farm may result in the death of several animals. When compared to diseases, carnivores may take only adult animals while diseases are most prevalent among juvenile livestock (Thompson *et al*, 2010). The loss of adult animals may be considered by farmers to be a big economic loss because of the capital investment in veterinary medicines and time taken to raise the animal. Moreover, farmers consider depredation as a total loss due to the fact that when wild carnivores attack and kill livestock they consume all edible parts of the carcass, whereas a sick or even a dead animal can be processed for household consumption (Nyahongo *et al.*, 2007). For this reason carnivores may be persecuted once encountered in a village or in the grazing area. To reduce the perceived conflict over livestock predation, farmers have been reported to poison carnivores (Stuart *et al.,* 1985; Berry, 1990; Holekamp and Smale, 1992). This study aims to assess livestock loss due to spotted hyena in selected villages of Rorya District. Specifically, the study intended to determine levels of livestock depredation along the landscape gradient from Rorya hills. In addition, it explored the coping strategies local communities deploy to mitigate the livestock depredation in the study area. Moreover, the study intended to investigate the main cause of livestock loss in the villages of Rorya District. Lastly, it explored the level of bushmeat consumption among local communities in the selected study villages.

MATERIALS AND METHODS

Study area

The study was conducted in three villages, namely: Chereche, Kowak and Omuga, in Rorya District, Mara Region (Fig 1) between July 2013 and June 2014 to cover for both rain and dry seasons. The District borders Kenya in the North and Tarime District in the East. In the South it borders Musoma Rural District and Uganda to the North-west.

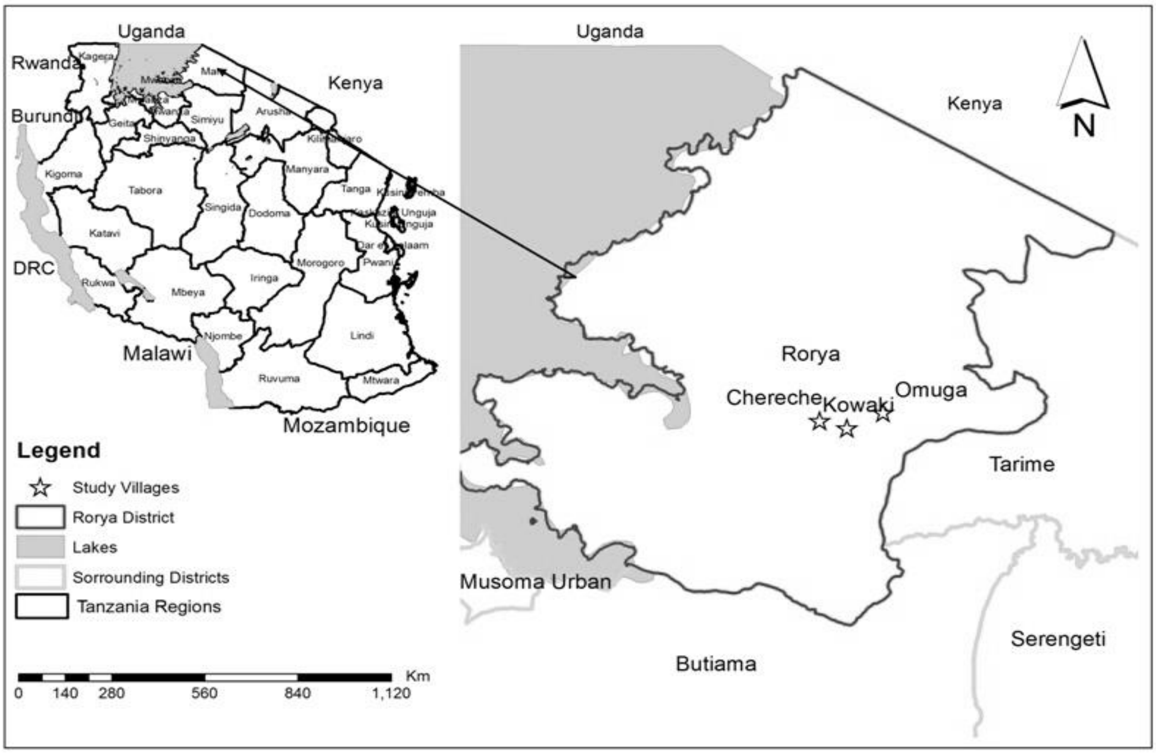

Figure 1: *Map of Rorya Figure 1: District indicating the study villages*

Climate and soils

Generally, Mara Region in which Rorya District is located can be divided into three major climatic zones namely; i) the northern highland zone that falls within Rorya District, Tarime Districts and part of Serengeti District. This zone receives an average rainfall of between 1250mm and 2000mm per year. It has two rainy seasons; a short one from September to January and a long rainy season lasting from February to June (Holmen *et al.*, 2006). This zone favours the growth of different annual and permanent crops including beans *Phaseolus vulgaris*, sorghum *Sorghum bicolor*, cassava *Manihot esculanta*, sweet potatoes *Ipomea batatas*, banana *Musa paradisiaca*, maize *Zea mays* and coffee *Coffea spp;* ii) the central zone covers much of Musoma District and eastern parts of Serengeti District. The zone receives between 900 and 1300 mm of rainfall per year and it favours the growth of crops such as rice *Oryza sativa*, maize, sorghum, finger millet, cassava, sweet potatoes and groundnuts *Arachis hypogaea*; iii) The southern zone is lowland area which includes a large part of Bunda District. The region's soils have been formed by weathering of granite rocks resulting into a wide range of soil types (Holmen *et al.,* 2006). Generally, soils vary from course and light to heavy and fine textured. Other soils include light sandy loams, grey clay particularly in the valley bottoms and in wetlands and black calcareous soils referred to as mbuga soils. In this zone various crops are grown including cotton.

Geology

According to Majule et al. (2009), geologically the large part of Mara region is composed of a flat sheet of dark grey basalt associated with metavolcanic rocks. The rocks belong to pre-cambrian age forming a base for the formation of younger rocks. Mara region has been classified into three areas on a geological basis including i) Northern highland: This occupies the whole of Tarime and Rorya Districts, parts of Serengeti and Musoma Districts and it consists of granite granodiorite foliated gneisses and magnetite, ii) Southern highlands: This occupies the western parts of Serengeti and large parts of Bunda Districts. It consists of mainly volcanic rocks of alkaline nature and iii) Central lowland: Mainly in Serengeti and parts of Bunda and Musoma which has rocks of Meta-volcanic nature and conglomerates.

Topography and drainage

The Mara Region lies between the low granite hills rising at about 100m above the gently sloping foothills, which lead down to rather narrow flooded areas of Musoma location, and Makoko foothills (URT, 2003). Other parts of the region are the areas in which plateau surface is broken up by long narrow hill ranges, which rise above rather flat low lands. There are several hills, which are within the region's area including the Ryamakongo hills, (1259 metres above sea level), Kibayo hills (1254 metres), Rorya hill and Nyabisonga hills. Generally, the topography of the region is undulating to rolling with wide valleys and occasional steep sided hills and this allows for different livelihood systems to interact within and across ecological gradients (Majule *et al*., 2009). In the region, it is only the Mara River that is perennial and is the river that forms the major drainage pattern with its tributaries flowing to Lake Victoria. Other streams flow to the lowlands forming flood plains, which are potential for pasture growth for livestock grazing.

Selection of study sites

The villages where this study was conducted were the same villages studied earlier in 2006 (Nyahongo *al*., 2007). Basing a study in these areas for the second time was important because the baseline data about human population size, livestock population and level of predation were available for comparison. Moreover, the communities from these villages complained of increased level of livestock depredation following an awareness campaign for spotted hyena conservation launched by researchers in 2006. People did not use poison to kill hyenas after that campaign and therefore, they perceived that population of spotted hyenas had increased. Three villages were purposely selected based on the distance from the village centre to Rorya hills, where the dens of hyena were thought to be located.

Chereche village is located close to the hill (within less than 1 km); Kowak is situated at an intermediate position (within 5 km of the hill), whereas Omuga is located at a largest distance (more than 10 km) from the hill. The three villages have approximately similar number of livestock and dogs per household, the economy of households in these villages do not vary greatly, and the livestock husbandry techniques are approximately the same. Thus, if hyenas in the area chiefly denned at the hill, Chereche village would be expected to experience more predation than either of the two other villages, with a decline in predation from Kowak village to Omuga village.

Research design

This study adopted snowballing research techniques where the first household visited was selected purposely by asking a village leader to identify the name of the household whose livestock or domestic dog had been attacked by spotted hyenas during the period of the last two years. Once the first victim was identified the household was visited and interviewed, thereafter, they were requested to nominate any household they know that have been affected by spotted hyenas. This was repeated until the saturated point was reached (i.e. no new household mentioned).

Data collection

This study used two sampling techniques; interview survey using standardised questionnaires. Furthermore, night holding bomas were inspected and any open gap found in them were measured and recorded. These bomas were also photographed for analysis of boma strength. Interviews were conducted in all households whose livestock had been attacked by hyenas in each of the three villages following snowballing techniques mentioned above. The total number of questionnaire conducted was 194, including 91 respondents from Chereche village; 59 respondents from Kowak and 44 respondents from Omuga.

A global position system (GPS) was used to record the location of each household interviewed. Respondents were requested to mention the number of livestock they own, and how many they lost due to hyena attack and those due to disease within the period of the past two years (i.e. from 2012 to 2014). Moreover, respondents were asked whether there were facilities to slaughter livestock in the village and whether they have a pit in which to dispose their household wastes and the remains from slaughtered animals. This information contributed to knowledge on factors likely to attract hyena to the villages. Interviews were conducted in Kiswahili and Luo. The later is the vernacular language spoken by local communities in the three selected villages. The interview was conducted in a way that a respondent could not link the intention of the researcher and the questions asked.

Data analysis

The analysis of data obtained from questionnaire was done using Statistical Package for Social Sciences (SPSS) version 16 for windows. Descriptive statistics were used to calculate means and standard error. Non-parametric statistical tests including the Kruskal-Wallis analysis of variance, the Wilcoxon matched-pairs signed rank test and the Mann-Whitney U test were used to compare median values of losses of different livestock due to depredation by spotted hyenas and those that died of diseases in and between study villages. Descriptive data were summarised as tables, figures and percentages. For all presented comparisons, $p < 0.05$ was considered significant.

RESULTS

Overview

The results presented here are those obtained through questionnaire, interview schedule and observations.

Age structure of household members

Information from households on the number of adult male, adult female and children in each household interviewed in each study village were analysed and are presented in Table 1. The findings indicate that the mean number of adult males' occupants per household in study villages was lower than the number of adult female Adult males in each household ranges from 0-5, while adult females ranges from 0-8. Mean number of children per household did not differ significantly (Kruskal-Wallis; $H = 1.781$, $df = 2$, $p > 0.05$) and the number of children per household ranged from 0-27.

Table 1: Age structure of sampled households in each village (Mean ± SE)

Village	Adult male	Adult female	Children
Chereche (n=91)	1.4 ± 0.1	2.0 ± 0.2	7.0 ± 0.6
Kowak (n=59)	1.4 ± 0.1	2.0 ± 0.3	7.0 ± 0.9
Omuga (n=44)	1.3 ± 0.1	2.0 ± 0.2	6.4 ± 0.6

Level of depredation along the gradient of distance from Rorya hill

The respondents from each household in the sampled villages along the gradient of distance from Rorya hills reported levels of livestock and domestic dog depredation, and which livestock species was most often attacked by spotted hyena. The data from the Village Executive Officers (VEOs) of the three villages following a livestock census conducted in 2013 states that there were 2,853 cattle at Chereche village, 4,200 at Kowak village and 3,600 from Omuga village. If spotted hyena predation were affected by the number of cattle per village we would expect cattle predation to be highest in Kowak and least in Chereche village (i.e. the expected pattern of predation would be Kowak > Omuga > Chereche). The same sources of information indicated that there were 1,560 sheep at Chereche village; 3,100 sheep at Kowak village and 2,700 sheep at Omuga village, which suggests if spotted hyena predation is affected by the number of sheep per village, then the expected pattern of predation would be Kowak > Omuga > Chereche. The numbers of goats reported in each village was 3,422 at Chereche village; 3,000 at Kowak village and 2,200 at Omuga village indicating that the predation pattern for goats should be Chereche > Kowak > Omuga. Combined data from all villages revealed that sheep were the species of livestock that was most often attacked by spotted hyenas in the study area (Figure 2). The second mostly often attacked livestock species were goats, followed by cattle, while dogs were the least often attacked.

Considering reported depredation by spotted hyenas along the gradient of distance from Rorya hills, Chereche village had most attack events followed by Kowak and Omuga village reported the lowest number of attacks. However, when the species of livestock was considered, the extent of cattle depredated differed significantly (Chereche > Omuga > Kowak) between villages (Kruskal-Wallis; $H = 10.674$, $df = 2$, $p < 0.05$). For sheep, there was no significant difference in livestock depredation between the villages (Kruskal-Walllis; $H = 4.014$, $df = 2$, $p > 0.05$). Levels of depredation of goats (Chereche > Kowak > Omuga) and dogs (Chereche > Kowak > Omuga) differed significantly between the three villages (Goat: Kruskal-Walllis; H = 6.110, df = 2, $p < 0.05$; Dogs Kruskal-Walllis: H = 6.704, df = 2, $p < 0.05$).

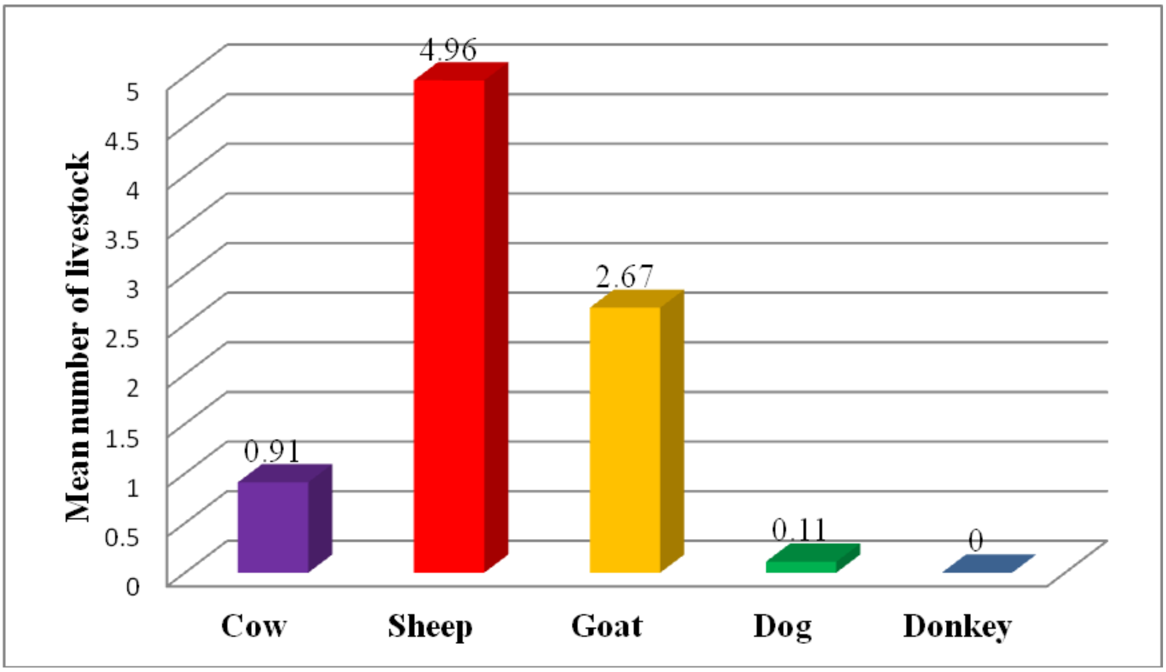

***Figure 2**: The mean number of animals per household claimed by farmers to be attacked by spotted hyenas (Pooled data)*

Factors attracting spotted hyenas to the villages

The data from Chereche, Kowak and Omuga villages indicated that only 56 households (28.8%, n = 194) had pits for household waste disposal while 138 respondents, (71.2%, n = 194) had no pits for household waste disposal; only disposing the wastes around the house or in the field (shamba). In addition, inspection of the night holding enclosures/bomas revealed that they were not predator proof. The photographs taken from Chereche, Kowak and Omuga villages revealed that that the majority of households in the study area constructed poor bomas that could not prevent wild carnivores attacking the livestock they contained (Plate 1, Plate 2 and Plate 3).

Coping strategies for livestock depredation

Livestock depredation is not accepted by farmers though can be tolerated to some extent. Farmers use different techniques to reduce level of depredation. The strategies usually involve killing of carnivores when encountered or blocking them through guarding and building night holding bomas that are supposed to be predator proof. However, building predator proof bomas may need more funds than many farmers have, hence they generally guard their livestock or poison the predators. When household members were requested to suggest the type of approach they use to guard livestock at night as a coping strategy against livestock depredation, the majority (85.1%, 165/194 respondents) claimed to use dogs and only six respondents (3.1%) claimed to use sturdy bomas. Few respondents (12.9%) claimed to do nothing. When household members were asked to suggest actions they usually take when their livestock are attacked or killed by spotted hyena, the majority (97.9%, 190/194 respondents) claimed that they do nothing while only four respondents (2.1%) admitted to use poison to kill spotted hyenas. When asked to reveal the types of poison they use, all suggested that they use pesticides called *thiodane*.

Plate 1. *A sample of night holding boma for goat, sheep and calves at Chereche Village*

Plate 2: *A sample of night holding boma for goat, sheep and calves at Kowak Village*

Plate 3. *A sample of night holding boma for goat, sheep and calves at Omuga Village*

Comparison of livestock loss due to diseases versus depredation

Combining data from all study villages we found that significantly more cattle were lost due to diseases than to depredation (Mann-Whitney: $U = 8{,}799.500$, $p < 0.0001$). Similarly, more domestic dogs were lost to disease that were depredated (Mann-Whitney: $U = 17{,}290.500$, $p < 0.05$). In contrast, more sheep were lost to wild carnivore depredation than to disease (Mann-Whitney: $U = 8{,}545.500$, $p > 0.0001$). There was no significant difference between losses of goats due to diseases and depredation (Mann-Whitney: $U = 17{,}379.500$, $p > 0.05$).

Availability and spatial variation of bushmeat

The data from three villages revealed that 90.2% of all respondents, (n = 194) claimed to not participate in bushmeat hunting whereas 9.8% admitted that they practiced bushmeat hunting. When asked to list the species they usually hunt, the species mentioned included African hare (*Lepus capensis*), dik dik (*Madaqua kirki*) and common duikers (*Cephalophus maxwell*); large ungulates were not mentioned probably due to the fact that they have been locally depleted.

DISCUSSION

The information reported here was gathered solely from respondents whose livestock were alleged to have been attacked by spotted hyenas, and not from those that rarely experience such attacks. The reported attacks on livestock were not independently verified hence we cannot exclude the possibility that the number of attacks might have been exaggerated, or included losses associated with poor management as reported elsewhere (Nabane, 1995; Infield 1996; Nyahongo *et al.*, 2007).

Based on the assumption that most spotted hyenas in the study area denned in the Rorya hills, we hypothesised that foraging distance might influence predation and hence predicted that predation should significantly decline as the distance between a study village and Rorya hills increased i.e. (Chereche > Kowak > Omuga). Overall, sheep were more often attacked by spotted hyena than other livestock or domestic dogs (Figure 2). Respondents claimed that sheep were typically quiet when attacked by spotted hyenas (Awiti Agack, personal communication, 2014). This behaviour by sheep has also reported elsewhere (Maleko *et al.*, 2012; Nyahongo and Roskaft, 2012). Even so, it is not known whether this aspect of the behaviour of sheep influences the choice of spotted hyena for livestock prey. Contrary to our prediction in relation to the spotted hyena foraging distance between each study village and Rorya hill, we found no effect of this distance on the level of sheep predation, which was similar across all three villages. Our alternative hypothesised was that spotted hyenas might be drawn to hunt more often in villages with the largest number of sheep, and if this were so we would expect Kowak village to have a significantly higher level of predation, which our results do not support. Even so, livestock census data indicated that all study villages held very large numbers of sheep (between 1,560 – 3,100), and thus it is perhaps not surprising that spotted hyenas are attracted to hunt in all study villages.

Goats were the second most often depredated livestock species in study villages (Figure 2) and the level of predation of goats significantly differed across villages, in accordance with our prediction concerning hyena foraging distance to Rorya hill (i.e. Chereche > Kowak > Omuga). Furthermore, the results of our analysis also supported our prediction in relation to the total number of goats per village, hence suggesting that both foraging distance and the number of goats per village might influence the level of hyena predation of goats in the study villages. However, given that we did not obtain similar result in relation to attack on sheep, further research is necessary to determine whether these results are robust, given that the significant difference in cattle predation across the three villages also failed to support the prediction of both hypotheses.

It is possible that Rorya hills might not be the only denning area for spotted hyenas in the study area. If dens and safe day-time resting sites occur in other locations, a strong effect of foraging distance from the Rorya hills would not occur. Also, spotted hyenas can travel long distances on foraging trips (Hofer and East 1993) hence a foraging distance of approximately 20km per night, between the Rorya hills and the most distant study village, would be unlikely to deter this species. In addition to the attraction of a high abundance of livestock within each study village at night, our result revealed that 71.2% of all respondents do not have pits for household waste disposal. Poor disposal of household waste and offal is known to attract spotted hyenas to villages and as a result may increase the chance of livestock attacks as reported by Kolowski and Holekamp (2006). Moreover, the fact that the majority of households surveyed by our study had bomas which could not protect livestock against spotted hyenas (Plate, 1, 2 and 3) is probably another important factor influencing hyena attacks on livestock in study villages.

When requested to suggest the action the respondents would like to take when their livestock are attacked or killed by spotted hyenas, the majority claimed that they do nothing (98%, n = 194). This suggests that the level of conflict is relatively low i.e. the level of depredation is low. Our results and those of similar studies in Tanzania show that losses of livestock to disease, particularly among economically valuable cattle (East, *et al.* 2012; Nyahongo and Roskaft, 2012), may result in a higher economic loss to farmer Nyahongo (2004) and Mwakatobe, *et al.* (2013) report that diseases are claimed to cause significantly large loss of livestock compared to depredation. Contrary to previous studies, it was revealed that diseases killed more cattle and domestic dogs compared to depredation while for sheep and goats the depredation was higher than diseases. Since this information was gathered from respondents whose livestock were killed by spotted hyenas, the number of livestock loss might be exaggerated perhaps with the intention of seeking compensation. In addition, since the veterinary service is poor in the villages, the weak animals may be left outside or in the bush unnoticed which may result to death or depredation by spotted hyenas.

An index of the abundance of wild herbivores around the villages may be estimated indirectly through the exploration of level of bushmeat hunting success per unit effort spent and the type of species that are usually caught. Results from the current study suggest that only small mammals like African hare, dik dik and common duikers are currently present in the area. However, when asked on their participation in bushmeat hunting, few admitted that they do hunt (8.5%). Although issues related to bushmeat hunting is sensitive that most respondents would not like to reveal due to worry of punishment, those few who admitted suggest that the hunting operation is taking place and that the few remaining small mammals are facing intensive harvest by both spotted hyena and human; and hence will be depleted soon. This tend to welcome the speculation that spotted hyenas attack livestock due to low densities of natural preys compared to densities of livestock and domestic dog in the area. Switching to different prey species when more typical wild ungulate prey species are scarce is common to many predators (Woodroffe and Frank, 2005).

CONCLUSION

Regardless of distance from Rorya hills, depredation of sheep by spotted hyenas occurred at similar level in all three villages and sheep were the livestock species most often attacked. Livestock depredation among the surveyed villages along the gradient of distance from the Rorya hills was similar for all livestock species except cattle where Chereche had the highest level of depredation compared to Kowak and Omuga. Moreover, local communities in the study area use different deterring methods to prevent livestock depredation by spotted hyenas. The most common strategy to prevent livestock depredation was using domestic dogs to protect livestock at night and very few reported the use of poison; a pesticide called *thiodane* and other weapons like spears for killing spotted hyenas. It is evident from the study that livestock diseases like tick-borne and worms were the main cause of livestock mortality compared to depredation. Furthermore, high depredation in villages are caused by poor livestock husbandry; weak night holding bomas, poor guarding of livestock, relying on domestic dogs to watch livestock at night and poor household waste disposal that attracts spotted hyenas. Lastly, but not least, the current study revealed that, few people in the villages are practicing illegal bushmeat hunting probably because the area currently only harbor small mammals such as African hare, dik dik and common duikers. Finally, our results indicated that the number of adult female per household in the study villages was almost twice the number of adult males. This might be due to the fact that in the area men practice polygamy, hence in some households, men married to more than one wife, which is a common practice in most part of Africa (Bharadwaj and Nelson, 2010).

RECOMMENDATIONS

Recommendation for action

i) Livestock keepers should build predator proof night holding bomas to reduce the levels of livestock depredation.
ii) Livestock keepers should engage in guarding their livestock at night and not relying on domestic dogs alone.
iii) Diseases are killing more livestock than depredation. It is recommended that the veterinary services in the villages be improved.
iv) The local government authority in co-operation with local communities should specify the location for domestic waste disposal outside villages which will help to discourage the frequent visiting of spotted hyenas to the villages.
v) Despite the low densities of natural prey for wild predators like spotted hyenas, yet local communities practice bushmeat hunting. The local communities should stop hunting these animals so that their population increases which might help to reduce depredation of domestic livestock by wild carnivores.

Recommendation for further study

i) The population size and the phylogeny of the spotted hyenas in Rorya District are not known, the study recommends for more data collection.

ii) To be able to efficiently set remote cameras for identification of spotted hyenas and other wild animals in the study area at night, the study recommend the procurement of small tents for researchers to use at night to protect cameras from theft.

iii) Further study on population size of different species of wildlife in the area is recommended.

iv) Education awareness to local communities in the importance of conservation is recommended.

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ACTIVITY PATTERNS OF BLACK-AND-WHITE COLOBUS MONKEY *(Colobus guereza caudatus)* IN RAU FOREST RESERVE, TANZANIA

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ABSTRACT

This study on black-and-white colobus monkey (Colobus guereza caudatus) was conducted in Rau Forest Reserve, Moshi, Tanzania investigating overall activities across age and sex groups. We used scan sampling to record overall activities. F ocal animal sampling to record activities across age and sex groups. Colobus monkeys in Rau Forest Reserve spent much time resting (57.7%), followed by feeding (27.7%) and less time on moving (10.8%) and social activities contribute only (3.8%). Across age groups, adults spent 60.7% of their time resting while juveniles and infants spent only 50% and 46.1% respectively. Furthermore, adults spent 21% of their time feeding, followed by juveniles 27.9% and infants 16.9%. Movements were more similar across ages (10.5-13.1%). Time engaged in social activities varied strongly among ages (adults 7.8%, juveniles 10.8%, and infants 23.8%). Sexes differed slightly in their activities, most notably with females spending almost twice as much time in social activities as males (8.0% vs. 4.3%). This difference seems to be dictated by the availability of social partners. Resting time in colobus monkeys is a strategy for energy conservation, although socialization is also particularly important for infants.

Key-words: Activity pattern; Black and white colobus monkeys; Colobus guereza caudatus; Rau Forest Reserve.

INTRODUCTION

Primates' activities can be determined by habitat types in which they are living (Cristobal-Azkarate and Arroyo-Rodriguez, 2007; Fashing et al., 2007; Riley, 2007; Wijtten et al., 2012). This is influenced by the availability of food, water, cover, and other environmental factors (Fernandez-Duque, 2003; Cristobal-Azkarate and Arroyo-Rodriguez, 2007; Riley, 2007). Because primates live in a variety of habitats, their activity depends on group size, site, time and individual variation (Fashing, 2001a; Teichroeb et al,. 2003; Wijtten et al., 2012). Some groups (age groups) tend to spend much time feeding while other groups spend more time grooming, playing and moving (Fashing, 2001a). Mountain forest colobus monkeys spend up to twice as much time feeding and six times moving, but less time resting, compared to colobus monkey in coastal areas (Fashing et al., 2007; Wijtten et al., 2012). Feeding activities tend to increase from morning to evening, major movements tend to occur in the late afternoon and resting tends to remain constant throughout the day (Teichroeb et al., 2003). Sexes differ in activity, for example females spend much time grooming and moving while aggression is much more common in males than females (Fashing, 2001a; Teichroeb et al., 2003; Fashing et al., 2007). Infants tend to use more time playing and less time grooming than adults (Fashing, 2001a). Adult colobus monkeys defend the territory (Fashing, 2001a).

Variation in activities is related to the strategies employed by primates to budget their energy (Stanford, 1991; Dasilva, 1992; Dasilva, 1993; Milton, 1998; Kingdon et al., 2008; Wijtten et al., 2012). Similarly to activity of black-and-white colobus monkeys, energy conservation strategies differ from one group to another, even at a single site (Teichroeb et al., 2003; Isbell and Young, 1993; Harris and Chapman, 2007). Also energy management can vary from one season to another and even between sexes (Dasilva, 1992; Fashing et al., 2007; Teichroeb et al., 2003). The diversity in activities of black-and-white colobus monkey might be due to energy conservation (Dasilva, 1992; Wijtten et al., 2012). For example, black-and-white colobus monkeys tend to move short distance and spend much of their time resting and feeding on available abundant food materials (Oates, 1977; Fashing, 2001a; Wijtten et al., 2012). Results obtained from various studies show that activities like grooming, vigilance, greeting, and playing take less time of black-and-white colobus monkey as compared to resting and feeding (Fashing, 2001a; Fashing et al., 2007; Wijtten et al., 2012). Activities can also be influenced by the number of individuals present in the group of primates (Isbell and Young, 1993; Kingdon et al., 2008). Individual vigilance declines with group size (Isbell and Young, 1993). Other scholars argue about the behavioral thermoregulation in colobus monkey, that they spend much of their time resting hence remain inactive for much time of the day. However, this needs much study to have it revealed (Fashing, 2001a).

Habitat loss is the primary threat facing species worldwide (Cronk and Fuller, 1995; Lowe et al., 2000; Park, 2004; Czech, 2005; Hens and Boon, 2005;

Chapman et al., 2007; Wong, 2011). This loss of habitats is a result of habitat destruction mainly influenced by human activities and other inevitable factors such as climate change (Wade et al., 2003). One of the habitats which has been degraded by humans is tropical forests, with a loss of 1.1% annually (FAO, 2000), or 9.4 million hectares per year (Wong and Sicotte, 2007), accompanied by fragmentation of remaining forest (Wong and Sicotte, 2007). That poses huge threat to the animals which rely on those areas for habitation (Wong and Sicotte, 2007). But before the animal goes to local extinction due to fragmentation and habitat loss, those threats can have impacts on animal's activities and movements in the forest refuge (Mbora and Meikle, 2004; Wong and Sicotte, 2007). For forest primates, including black-and-white colobus monkeys, fragmentation and loss of forests are a threat (Fashing, 2002). For the countries that hold a population of primates forest loss is at the rate of 120,000km^2 in each year (Wong and Sicotte, 2007). Rapid increase in human population in African forests has resulted into high rate of deforestation which has posed great threats to colobus populations (Anderson et al., 2007; Jansson, 2011). As a result of deforestation, colobus monkeys are now confined to fragmented forest habitats in East Africa (Kanga and Heidi, 2000; Anderson et al., 2007; Jansson, 2011). The majority of primate populations, including colobus monkeys, have been threatened by deforestation, habitat fragmentation and habitat degradation (Fashing, 2002; Boyle 2008; Jansson 2011). Although black-and-white colobus monkey habitat has been destroyed by humans, the species is listed as least concerned (LC) by IUCN despite being locally threatened (Kingdon et al., 2008; Jansson, 2011). Numerous species of primates inhabit lower quality forest habitats but are capable of surviving; therefore studies in those areas will expand the understanding on their behavioral ecology (Wong and Sicotte, 2007). The studies in primate behavior including black-and-white colobus monkeys in different forest fragments can help to give information related to time spent in looking for food and habitat quality (Zanette et al., 2000; Wong and Sicotte, 2007). In high quality habitat, individuals should spend less time travelling and foraging compared to lower quality habitat (Onderdonk and Chapman, 2000). However, much time spent in search for food as affected by habitat quality affects the activity of the primates (Wong and Sicotte, 2007).

Studies of black-and-white colobus monkey activity have been conducted at various sites (Wijtten et al., 2012). Oates (1977) described activity and diet of black-and-white colobus monkeys (*Colobus guereza*). Dasilva (1992) found western black-and-white colobus to be a low-energy strategist in Tiwai, Sierra

Leone. In Kakamega forest, Fashing (2001a) also described activity and ranging of guereza. Activity of *Colobus angolensis ruwenzorii* was described by Fashing et al. (2007) in Nyungwe Forest, Rwanda. In western Africa, Wong and Sicotte (2007) studied the activity *Colobus vellerosus* in three groups at the Boabeng-Fiema Monkey Sanctuary in Ghana. In East African Coastal Forest, activity of colobus monkey was described by Wijtten et al. (2012). The study conducted by Jansson (2011) in Diani Forest, Kenya focused on feeding ecology of black-and-white colobus monkey. In the same study area Dunham (2013) examined the activity of black-and-white colobus in different habitats of southern coastal forest of Kenya. The study conducted by Groves (1973) in Usambara Mountains, didn't describe about black-and-white colobus monkey ecological activities.

Black-and-white colobus monkeys (genus *Colobus*) are Old World monkeys in the family Cercopithecidae and subfamily Colobinae (Gron, 2009; Jansson, 2011). This genus includes five species with several subspecies (Wilson and Reeder, 2005). In the species of *Colobus guereza* eight subspecies exist (Kingdon et al., 2008; Jensz and Finley, 2011).These species includes *C. g. caudatus*, our study species, is mainly found in the regions of Mt. Kilimanjaro (Groves, 2001; Gron, 2009; Jensz and Finley, 2011). *C. g. guereza* occurs mainly in Ethiopia while *C. g. dodingae* is the only species of colobus in southeastern parts of Sudan (Gron, 2009; Jensz and Finley, 2011). *Colobus guereza gallarum* is restricted to Ethiopian highlands on the eastern side of Rift Valley while *C. g. occidentalis* is distributed from Uganda and southern Sudan up to western parts of Africa (Gron, 2009; Jensz and Finley, 2011). In Mount Gargues areas *C. g. percivali* is found with *C. g. kikuyuensis* in central Kenya (Gron, 2009; Jensz and Finley, 2011). In western Kenya and northern-southern Tanzania C. *g. matschiei* is widely distributed (Gron, 2009; Jensz and Finley, 2011). This species (*C.g caudatus*) is a large colobus monkey with distinctive black and white pelage (Estes, 1991; Groves, 2001; Gron, 2009). Colobus males are larger than females, and only males possess a white unbroken stripe on the buttock (Estes, 1991; Fashing, 2001a; Gron, 2009; Kim, 2002). Infant colobus monkeys tend to have whole body covered with white hairs (Estes, 1991; Kim, 2002). Some of these species do not have while others have reduced thumb as the adaptation for moving across the arboreal region (Kim, 2002; Tague, 2002).

Black-and-white colobus monkeys are diurnal, arboreal primate species found in tropical rain forests and montane forests of Africa where they mainly feed on leaves and fruits (Dasilva, 1992; Fashing, 2001b; Anderson et al., 2007; Jansson, 2011; O'Dwyer, 2011; Huffman, 2013). This species of colobus monkey is widely distributed and always abundant within the African equatorial regions dominated by forests habitat from lowlands up to 3000 m.a.s.l (Estes, 1991; Kim, 2002). Black-and-white colobus monkeys live in small groups called troops, usually with only one dominant male, but bachelor groups do exist (Kim, 2002; Jansson, 2011). In larger troops two or more dominant males control the group (Jansson, 2011). A single troop of black-and-white colobus monkey comprises three to fifteen members (Kim, 2002). The black-and-white colobus monkey life span appears to be around twenty years in the wild and twenty nine years in captivity (Kim, 2002).

We assessed activity of black-and-white colobus monkeys (C*olobus guereza caudatus*) in Rau Forest Reserve, Tanzania. We focused on differences among age groups and between males and females. This information will help to understand the energy budget of this species, and will provide basic information on foraging and ranging that can be applied to conservation.

MATERIALS AND METHODS

Study area

Rau Forest Reserve (3° 23' S and 37° 22' E) is 3km SE of Moshi in the Kilimanjaro region of Tanzania. It covers an area of 25km^2 (Kamukala and Crater, 1993; Rodgers, 1993; Petro, 2009) from 730 to 765m elevation (Kamukala and Crater, 1993; Lovett and Pócs, 1993; Petro, 2009). Annual rainfall is approximately 870mm with temperatures of 26°C in February and 21°C in July (Lovett and Pócs, 1993; Rodgers, 1993). Rau Forest Reserve is mainly dominated by ground water forest but Rodgers (1993) classified the reserve vegetation into natural ground forest, swamp forest and woodland forest. The reserve has diverse bird life and several large mammal species including black-and-white colobus monkey, blue monkey and Kirk's dik-dik (Tanzania Trails, 2014). The soils of the Rau Forest Reserve are volcanic in origin with alluvial sand and loam rich in gleysols and fluvisoils (Lovett and Pócs, 1993; Rodgers, 1993).

Data Collection

This study involved both focal sampling and scan sampling; however a reconnaissance survey was conducted in the study area before the implementation of those methods. During the reconnaissance survey, we selected groups that were already habituated by human activities, influenced by the road passing through the reserve and tourism activities.

We collected activity data for 14 days from morning (7:00-8:00h) to evening (15:00-17:00h) in June, 2014 (Teichroeb et al., 2003; Wong and Sicotte, 2007). Focal observation and recording were done for 5 minutes at 15 minutes intervals throughout the day (Fashing, 2001a; Teichroeb et al., 2003). After spotting a monkey, we waited five seconds before starting recording to avoid over-representing eye-catching activities like moving (Teichroeb et al., 2003). The focal adult individual was selected opportunistically (Fashing, 2007). If the focal adult individual was lost before the end of the day, another adult individual was selected and observation and recording were conducted as long as possible (Fashing, 2007). Upon sighting of individual, the first activity held for 5 seconds was recorded (Mekonnen et al., 2010). If the individual was involved in more than one activity for example during social interaction, recording was done into sequence of those behaviors occurred during 5 seconds (Di Fiore and Rodman, 2001). Group activity was recorded every 15 minutes by scan sampling to determine activity which was done by at least 50% of the group members (Altmann, 1974).

Five activity categories were recorded as modified from Mekonnen et al. (2010), feeding, moving, resting, social and others. Feeding involved ingestion and masticating of plant or prey. Moving referred to the activity which leads to the changing of spatial location either by walking, running or jumping. Resting includes all activities which the individual was physically inactive either sleeping or sitting. Social includes grooming, playing, mating, aggression and greeting. Others include any activity which did not fit into the above categories, such as drinking, defecating, and alerting.

For differentiating age categories, we classified adults to include all monkeys that have attained reproductive maturity and full body size (Fashing, 2001a). Juveniles included individuals smaller than adults but not carried by their mothers, while infants were carried by their mothers at least occasionally (Fashing, 2001a).

Data Analysis

To represent the overall activities of the colobus monkey the ratios of the number of records were transformed into percentages (Fashing, 2007; Wijtten et al., 2012; Teichroeb et al., 2003). Chi-square tests and ANOVA were used to test for significant difference on the overall daily activity and in time spent per each of the activities observed across age groups. Furthermore, student t-test was used for comparison of time spent on the activities across the sex groups (Wijtten et al., 2012). Kolmogorov-Smirnov test was used to test for normality (Ehlers Smith et al., 2013). Spearman's rank correlation coefficient (r_s) was used to test the relationship between activities conducted at different periods of the day (Dasilva, 1992). To assist data analysis SPSS 21, MedCalc version 12.5.0.0 and Microsoft Excel 2013 were used.

RESULTS

A total of 3,338 activity observations were collected from both focal animal sampling and scan sampling from one group with mean of 9.86 SD± 1.77 with 8 to 12 individuals. We conducted a mean of 25.36 SD± 0.75 scans per day with a total of 360 scans. Other activities like defecation, urination and aggression did occur outside of sampling time; they were recorded but not involved in the analysis. Monkeys foraged most heavily on *Ficus sycomorus* (flowers), *Ficus exasperata* (leaves and fruits), *Delonix regia* (leaves) and lianas (leaves).

Overall activity

Monkeys spent much of their time resting (57.7%) and feeding (27.7%) while less time was spent on moving (10.8%) and social activities (3.8%) but the difference between these activities was not statistically significant Chi-square: $\chi^2 = 4.35$, P = 0.98 (Fig. 1). The social activities we observed were grooming and aggression, which were done by adults, and playing by infants. Grooming was mostly recorded within the group while aggression was both intra- and inter-group (Fig. 1). This form of activity was similar with other studies of activity of black-and-white colobus monkeys (*Colobus guereza*) conducted in Africa, that they spend more time in resting and feeding than other activities (Table 1).

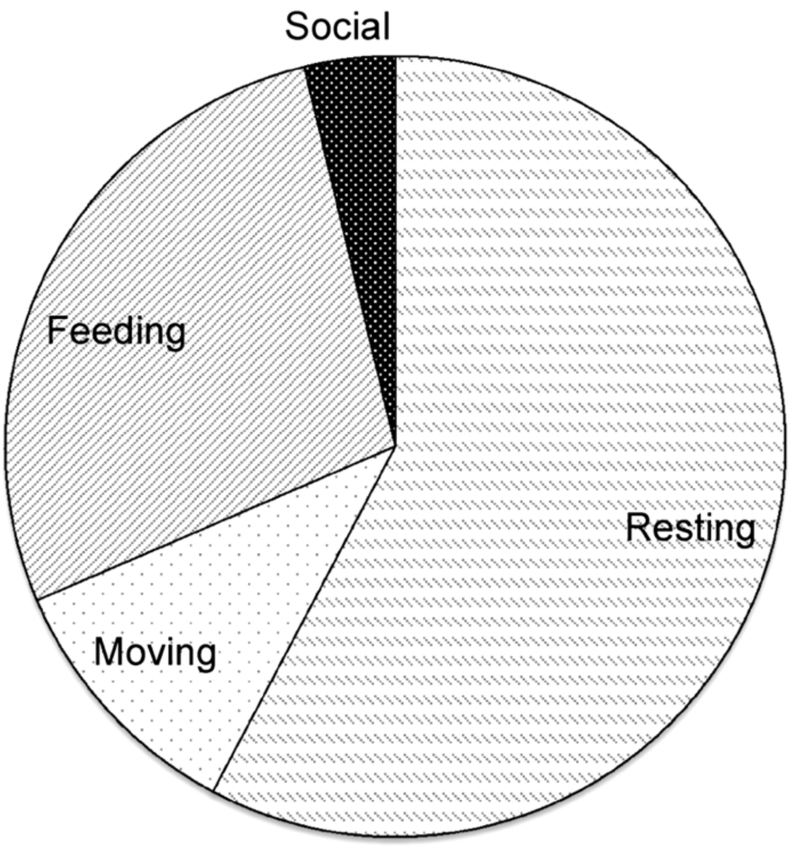

Figure 1: *Overall activity for black-and-white colobus monkey in Rau Forest Reserve (n = 360).*

Table 1: Comparison of activity (% of time) of black-and-white colobus monkeys (*Colobus guereza*) groups with other studies in Africa.

Study Area	Source	Group Size	Resting	Feeding	Moving	Social
Kibale Forest, Uganda	Oates (1977)	9	57	20	5	11
Ituri Forest, DRC	Bocian (1997)	8-10	44	24	24	5
Kakamega Forest, Kenya	Fashing (2001a)	10-13	63	28	2	6
		5-8	64	23	3	10
Rau Forest, Tanzania	This study	8-12	58	28	11	4

Table modified from: Teichroeb et al. (2003).

Note. *Values presented in the table above are percentages of time or records spent in a specified activity. Some of the social percentages were calculated by adding several of the original authors' categories together.*

Daily activity varied from morning to evening although the variation was not statistically significant (ANOVA: F = 1.18, P = 0.35). Resting was high at all times of day while feeding tended to be high in morning and evening and slightly lower during the afternoon. Movements of the group were higher in the morning and afternoon, becoming lower in the evening. There was a significant negative relationship between feeding and moving from morning to evening daily (Spearman's rho: r_s = -0.88, P = 0.02) while social activities ware fairly constant and at low level throughout the day (Fig. 2).

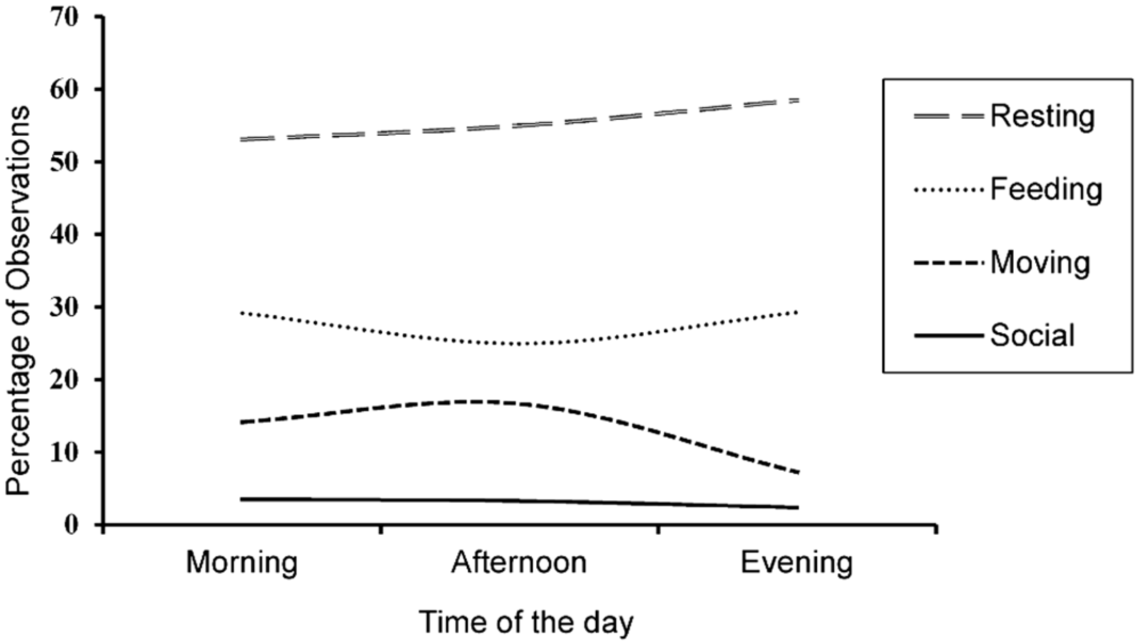

Figure 2: *Temporal activity throughout the day.*

Activity across age groups

Adults spent about 60% of their time resting while juveniles and infants spent only 50% and 46% respectively (Fig. 3) (ANOVA: F = 2.04, P = 0.16). Feeding varied significantly with adults spending 21%, juveniles 27.9% and infants 16.9% of their time taking food (ANOVA: F = 5.09, P < 0.05). Moving didn't vary significantly across age groups with adults spending 10.5%, juveniles 11.3% and infants 13.1% of their time in this activity (ANOVA: F = 0.57, P = 0.57). There was a significant difference in time spent in social activities across age groups with adults spending 7.8%, juveniles 10.8% and infants 23.8% of their time (ANOVA: F = 7.80, P < 0.01).

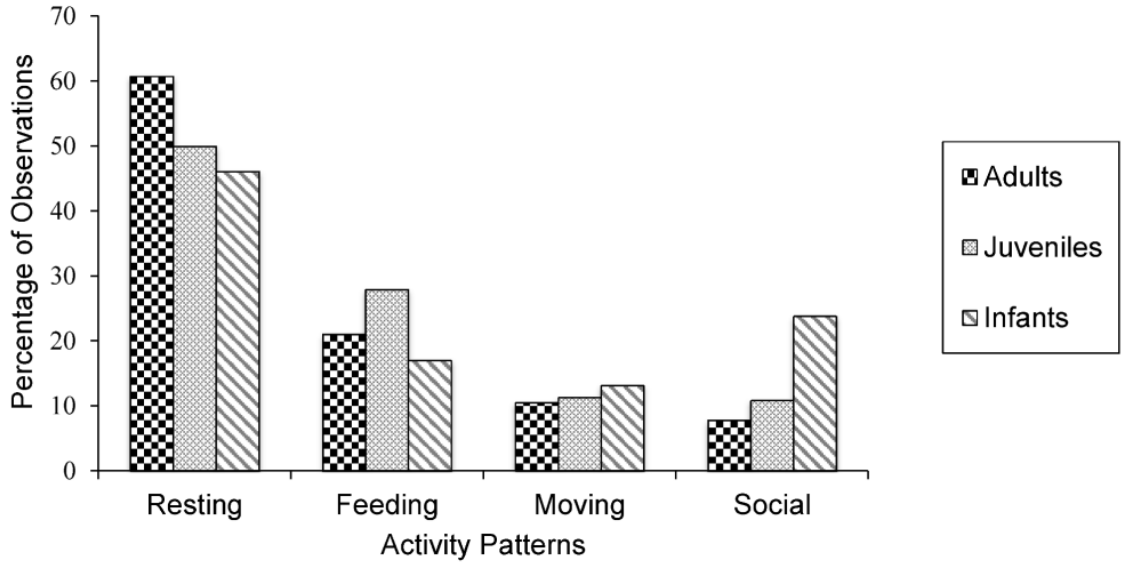

Figure 3: *Comparison of time spent on different activities (resting, feeding, moving and social) across age groups (adults, juveniles and infants).*

Activity across sex groups

There was no significant difference between sexes in resting (Fig. 4; males 62.0% and females 52.7%; t-test: t = 0.24, P = 0.81), feeding (males 19.2% and females 21.1%; t-test: t = -1.05, P = 0.31) and moving (males 14.4% and females 18.1%; t-test: t = 1.81, P = 0.09). The only significant difference was observed in social activities (males spent 4.3% and females 8.0%; t-test: t = -6.06, P < 0.01). Social activities mostly recorded in males involved aggression and vocalization while females' was grooming.

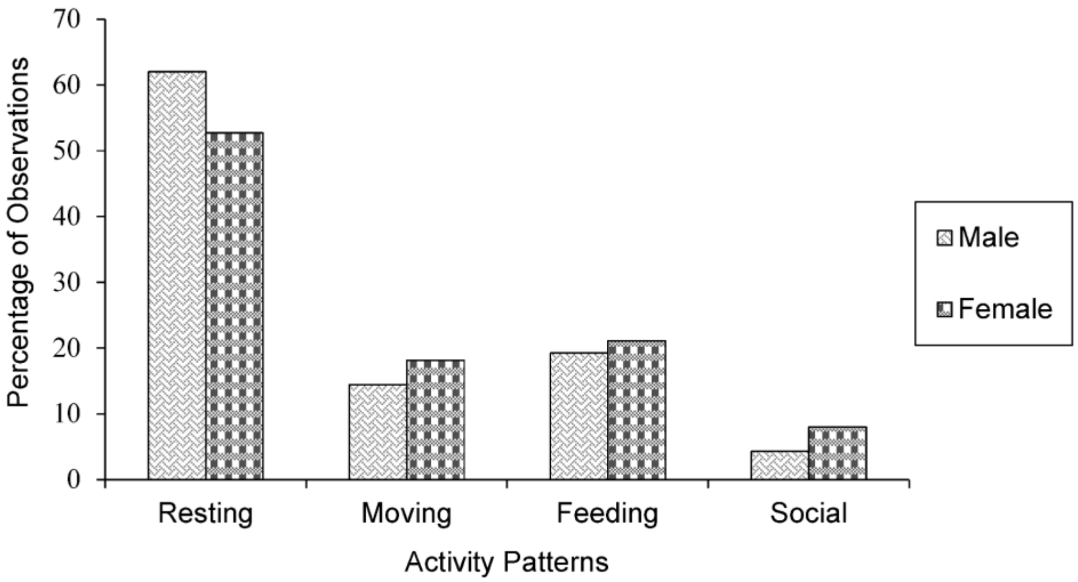

Figure 4: *Variation in activities by adult males and females.*

DISCUSSION

Overall activity

Similar to other studies on activity patterns of black-and-white colobus monkey, *Colobus guereza* in Rau Forest spent much time resting and feeding (Table 1). Compared to other studies in Uganda and Kenya, white colobus monkeys at Rau spent a similar amount of time resting and feeding, although they moved more. colobus monkeys at Ituri Forest, DRC, rested less and moved more than even Rau monkeys (Oates, 1977; Dasilva, 1993; Bocian, 1997; Fashing, 2001a). As argued by other authors, high resting might be due to behavioral thermoregulation with colobus resting under shaded tree canopies during afternoon and in sunny canopies in the morning and evening (Dasilva, 1992; Dasilva, 1993; Oates, 1977; Fashing, 2001a;). Also much time in resting might be needed to assist food digestion as colobus monkeys feed on cellulose-rich food materials requiring long gut passage times (Dasilva, 1992; Tovar et al., 2005; Fashing, 2007; Matsuda et al., 2009; Grant, 2010; Mau and Südekum, 2011).

Monkeys in Rau Forest spent more time resting and feeding than moving or engaged in social activities (Fig. 1). This variation in activity can also be due to energy conservation strategies (Stanford, 1991; Dasilva, 1992; Dasilva, 1993; Milton, 1998; Kingdon et al., 2008; Wijtten et al., 2012). As a result of energy conservation, colobus monkeys tend to move short distances and spend much time resting while feeding on the abundant food available (Oates, 1977; Fashing, 2001a; Wijtten et al., 2012). Difference in activity with other studies (Table 1) might be due to variations in habitats, from coastal forests to montane forests (Oates, 1994; Teichroeb et al., 2003; Fashing et al., 2007). Data collection techniques also lead to differences in activity from one study to another. Some researchers recorded the first behavior which lasts over 5 seconds while others recorded the behavior held by 5 seconds after spotting the focal animal and others record behavior instantaneously (Grimes, 2000; Fashing, 2001a; Teichroeb et al., 2003; Fashing et al., 2007). These differences in data collection methods may impact findings (Isbell and Young, 1993; Teichroeb et al., 2003; Matsuda et al., 2009).

Activities of monkeys in Rau Forest varied but not significantly over the course of the day (Figure 2). Resting tend to be at high in all times of the day but peak in the evening. Feeding tended to be higher in the morning and evening, suggesting that colobus monkeys feed more at cooler times of day. Movements were negatively correlated with feeding, peaking in the afternoon and less in the morning and evening, suggesting that black-and-white colobus monkey move less when they are feeding. The results for daily patterns of resting and feeding activities are consistent with other published studies of colobus monkeys daily activity (Oates, 1977; Bocian, 1997; Teichroeb et al., 2003).

Activity across age groups

Activity by age groups did not vary significantly (Fig. 3). Adults spent more of their time resting than juveniles and infants. While resting, males were often vigilant, while females were associating with infants (Grimes, 2000; Fashing, 2001a). Also, as animal become older they become less active and rest more (Grimes, 2000). Juveniles were observed spending more time feeding than adults and infants as similarly observed by Fashing (2001a) in one group of colobus monkey at Kakamega Forest. Movements across the age groups tend to be more or less similar probably because colobus monkeys move as a group (von Hippel, 1996; von Hippel, 1998; Jansson, 2011; Public Broadcasting Service (PBS), 2014). Infants spend much of the time in social activities, probably due to their involvement in a wide range of activities including playing, which is common at other ages (Fashing, 2001a). Infants spent time in playing while adults are resting (Grimes, 2000). The results of feeding and moving across age groups do conform to the results published by Fashing (2001a) in two groups of black-and-white colobus monkeys in Kakamega Forest, Grimes (2000) in Entebe Botanical Gardens, and O'Dwyer (2011) in Diani Forest.

Activity across sex groups

Sexes differed in activity at Rau Forest: males spent more time resting as also noted by Fashing (2001a); Teichroeb et al. (2003); Fashing et al. (2007); O'Dwyer (2011); Wijten et al. (2012). Resting in males was accompanied with other activities such as vigilance, which is less practiced by females (Grimes, 2000; Fashing, 2001a). As described by Fashing (2007), body size has a positive relationship with resting time in African colobines, as males are larger than females and rest more. Feeding, moving and social activities were more observed in females than in males (Fig. 4) similar with other studies (Grimes, 2000; Fashing, 2001a; Fashing et al., 2007; Wijten et al., 2012; Huffman, 2013). Females feed more so as to cover their increased nutritional requirements resulted from suckling infants (Teichroeb et al., 2003). As much they need more food hence they more search for it (Riley, 2007). Social activities in females are influenced by the availability of social partners as most groups of colobus monkeys are dominated by single male (Dunbar, 1976; Estes, 1991; Dunbar, 1992; Kim, 2002; Teichroeb et al., 2003; Kutsukake et al., 2006; Jansson, 2011). In this study four incidences of aggression were observed (only one during sampling time). Three incidences involved focal male chasing males from another group , in another the male was chasing a blue monkey, and another involved a male chasing an owl. One incidence of aggression, observed during sampling time, involved the group being chased by a male from another groupafter the focal group entered another group's home range. Incidences of aggression in *C. guereza* are rarely seen and if they occur, mostly involve males (Grimes, 2000; Fashing, 2001a; Fashing, 2001b; Sicotte and Macintosh, 2004). This is an indication that competition in colobus monkeys is mostly over access to females and not for food (Fashing, 2001a).

Feeding habits and competition on colobus monkeys in Rau Forest Reserve

Although determining the feeding habits and competition wasn't a major focus of this study, it was observed that colobus monkeys in Rau forest feed on leaves, flowers and fruits. Generally, colobus monkeys in this area mainly feed on leaves and fruits, as is typical for colobus (Grimes, 2000; Fashing, 2001b; Chapman et al., 2002; Jansson, 2011; O'Dwyer, 2011). The trees used in Rau Forest Reserve included *Ficus sycomorus* (flowers/fruits), *Ficus exasperata* (leaves and fruits), *Delonix regia* (leaves) and lianas (leaves). From 72 tree species identified by O'Dwyer (2011), *Ficus sycomorus*, *Ficus exasperata* and *Delonix regia* are among the tree species utilized by six troops of black-and-white colobus monkeys as food materials. Fashing (2001b) mentioned about colobus monkeys spending more time feeding on *Ficus exasperata* from 32 tree species in Kakamega Forest, Kenya. Among 42 trees species present in Diani Forest, *Delonix regia* is more highly consumed by black-and-white colobus monkeys than other trees (Jansson, 2011). Lianas are a common food component for monkeys including the black-and-white colobus monkeys (Peres, 1994; Davies et al., 1999).

CONCLUSIONS AND RECOMMENDATIONS

Overall activity of black-and-white colobus monkey do vary, as they spend much time (more than 50% of their time) in resting and feeding while spending less time in social activities like grooming. These variations do occur also between age and sex groups. Adults rest more than juveniles and infants while juveniles feed more than adults and infants. However, infants spend much of the time in social activities especially playing. Regarding activity across sex groups, males rest more than adult females and females socialize (grooming) more than males. The variations in overall activity are due to energy conservation strategies and more time for digesting cellulose food materials hence more resting time. Body size tends to be the factor for much resting time across age and sex groups. Availability of social partners was the factor for females to socialize much than males while the involvement of infants into a wide range of social activities was the factor for infants to be involved much in social activities than adults and juveniles.

Our results from Rau forest are based on a single group studied for a short period. It would be useful to study additional groups, and to compare activity across seasons. These studies will help to determine whether the population in isolated Rau forest can be sustained.

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CAN WATER RESOURCES LEAD TO PRO-POOR GROWTH?: A COMPARATIVE STUDY ON LAKE VICTORIA AND LAKE TANGANYIKA FISHERIES IN TANZANIA

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ABSTRACT

Fish resources have direct link to fishers' incomes. However, majority of fishers in developing countries who are involved in fishing and related activities have remained poor. This study, using Participatory Rural Appraisal (PRA) methodology has assessed the extent to which fisheries in Lake Tanganyika and Lake Victoria is for Pro-poor growth by focusing on the distribution of incomes between fishers and fishing gear owners. With respect to Lake Tanganyika fisheries, the net monthly income accruing to fishers and fishing gear owners during high catch season (October-March) was relatively higher compared to the net monthly income accruing to Lake Victoria fishers and fishing gear owners during high catch season (May-November). With Lake Tanganyika fisheries, fishing gear owners took the lion's share of the net income that was generated, but still fishers also netted relatively higher incomes during high catch season. A fisher who earned the highest monthly income netted $ 3,400 while one with lowest netted $ 600. The majority of fishers (17 fishers out of 35 fishers) each netted between $ 1875 and $ 3750. With respect to fishing gear owners, the highest monthly income earner netted $ 13,750 while the lowest income earner netted $ 1500. However, net monthly income earned by both fishers and gear owners during low catch season (April-September) were low. With respect to Lake Victoria fisheries, the majority of fishers (35 fishers out of 53 fishers), each generated net monthly income that ranged between US$ 161-480 during high catch season. And during low catch season (December-April), out of 53 fishers, 46 fishers each generated net monthly income of US$ 40. Fishing gear owners were relatively far better in both seasons.

Key words: Water resources, Pro-poor growth, Lake Victoria, Lake Tanganyika

INTRODUCTION

Millions of people dwelling within and around Lake Tanganyika and Lake Victoria basins derive food and livelihood from fisheries. The lakes and their basins support a wide range of subsistence and commercial activity as well as a remarkable assemblage of tropical flora and fauna, including highly diverse populations of endemic fish. According to Kimirei *et al*. (2006), the lake's commercial fishery has essentially been based on the two *clupeids* and *Luciolate* s*tappersii*. Clupeids are generally the most abundant species, although there is often an inverse relationship in catch numbers between clupeids and *Luciolate* s*tappersii.*

Reynolds *et al* (1999) point out that local fishers are almost exclusively men; generally fall within the range of 18-50 years; tend to have low levels of formal education (lack of primary school education); often originate from places other than their current landing site bases; and generally engage in fishing as their principal job, though are commonly involved in subsistence or combined food/cash crop farming as secondary occupations.

Agriculture is also conducted along with fishing. However, women are the major stakeholders involved in agriculture. Agriculture is the second income earner for households in the lake basins. The major crops that are cultivated in the Lake Tanganyika basin include but not limited to palm trees, cassava, beans, maize and bananas. The crops provide the households with food and the surplus is sold to earn money for meeting other household needs such as paying school fees for their children. The basin supplies palm oil for cooking in various market centres in the Great Lakes region. On the other hand, the major crops that are cultivated in the Lake Victoria basin, among other, include cotton, maize, banana, coffee. Along with agriculture, people in this region practice cattle keeping.

Lake Tanganyika is shared by Burundi, Tanzania, Democratic Republic of Congo (DRC) and Zambia and lies at 773 m above mean sea level. It is 673 km long, has a surface area of 32,900 km^2 and a maximum width of 48 km. The maximum depth is 1,470 m, making it the second deepest lake in the world. The average depth is 570 m and volume is 18,800 km^3 (Coulter 1966). The areas under jurisdiction of the four riparian states are Burundi (8%), Tanzania (41%), DRC (46%) and Zambia (6%) (Coenen *et al*. 1993).

There are three recognizable types of fisheries on the Lake Tanganyika: industrial, artisanal and traditional. The industrial fishery started back in 1954 when Greek fishermen introduced the purse seine. The artisanal fishery uses mainly catamarans and the traditional subsistence fishery uses many different gears such as gill-nets, hooks and line, scoop-net and traps (Bilame 2013).

Based on collected aerial and parallel ground surveys (FAO 2000), Lake Tanganyika hosted 44,960 active fishers, 18,240 operational fishing crafts and 786 landing sites. Despite the lack of current data on fishing pressure, landing sites and the number of canoes, the instability in the great lake region has had far reaching effects on fishing pressure and landing sites. A number of piracy incidents have been taking place particularly on the side of Kigoma significantly affecting fisheries on the Tanzanian side. Fisheries in Lake Tanganyika are important source of incomes for its riparian communities. Two categories of fisheries exist on the lake, offshore (pelagic) and inshore (demersal) O'Reilly *et al*. (2006). Pelagic fishery has historically been the more sustained yielding over 167,000 metric tonnes per year. However, because of the influence of climate change that lowers primary productivity of the lake (O'Reilly *et al*. 2003) the pelagic fishery is thought to be in decline (Kemerei 2005).

On the other hand, Lake Victoria, the largest of all African lakes, is also the second widest freshwater body in the world. It has a surface area of about 69,000 km^2 shared by three countries with a land drainage area of slightly over 181, 000 km^2. The lake surface area per country is: Tanzania 33,756 km^2 (49%), Kenya 4113 km^2 (6%) and Uganda 31,001 km^2 (45%). It should be noted that the late 1980s and 1990s saw radical oscillations in Nile perch fisheries in the lake. Prior to this period, fishing was predominantly artisanal and for local consumption. From this locally-based fishery, with little capital investment from outside, emerged the present fishery system, dominated by national and international capital, a change which is the result of the strong demand in the global markets for the Nile Perch (IUCN 1999).

The predominantly artisanal fisheries of the Nile perch that had existed for several years failed to compete with the commercial fisheries. As result, this rendered artisanal fishermen jobless, however, some managed to get employment in the commercial fisheries of the Nile perch but other artisanal fishermen had to shift to artisanal fishing of Sardines--a fishing sub-sector that did not attract commercial fishermen (Bilame 2012). Since may artisanal fishermen moved from artisanal Nile perch fisheries to Sardine fisheries, stiff competition in fishing Sardines emerged and that led to over-fishing of the species, partly because of the increased catch efforts and partly because of the use of fishnets that have small holes that capture pre-mature sardines. This is also supported by Jansen (1997) and Bilame (2011b) who argue that in the pre-Nile perch regime, the processing and trading sector of the traditional fisheries was almost totally dominated by small operators being based in the local communities around the lake. The majority of the people involved both in processing and trading were women living in the local communities close to the lake.

According to Jansen (2006), the development of fisheries at Lake Victoria is determined largely by an alliance between the authorities and national and international investors in the export industry, and the choices made by these actors in the fishing sector affect job opportunities, living conditions and food security for millions of people who depend on fish for employment and food. There is a wide gap between the external actors who invest in export fishing and the local population.

The general objective of this study was to examine how fishery sector can lead to pro-poor growth in developing economies by engaging a comparative analysis of Lake Victoria and Lake Tanganyika fisheries in Tanzania. Specifically, the study sought to examine the fishing characteristics in the two lakes, whether there are some similarities or otherwise, assess the levels of incomes generated and their expenditure pattern and to determine whether the incomes generated indeed suffice for pro-poor growth.

METHODOLOGY

Location of the Study Area

With respect to Lake Tanganyika fisheries, Katonga and Kibirizi landing sites in Kigoma municipality were the study area. These two landing sites were selected because they are the largest landing sites in Kigoma municipality. Furthermore, unlike other landing sites where fishing gear owners live near the landing sites; gear owners at Katonga and Kibirizi were residents of Kigoma urban, although they were necessarily not all born in Kigoma urban. The unit of analysis was a fishing camp composed of four fishers plus an owner of the fishing gears. Fig. 2.1 below shows Lake Tanganyika map and the two landing sites that were surveyed.

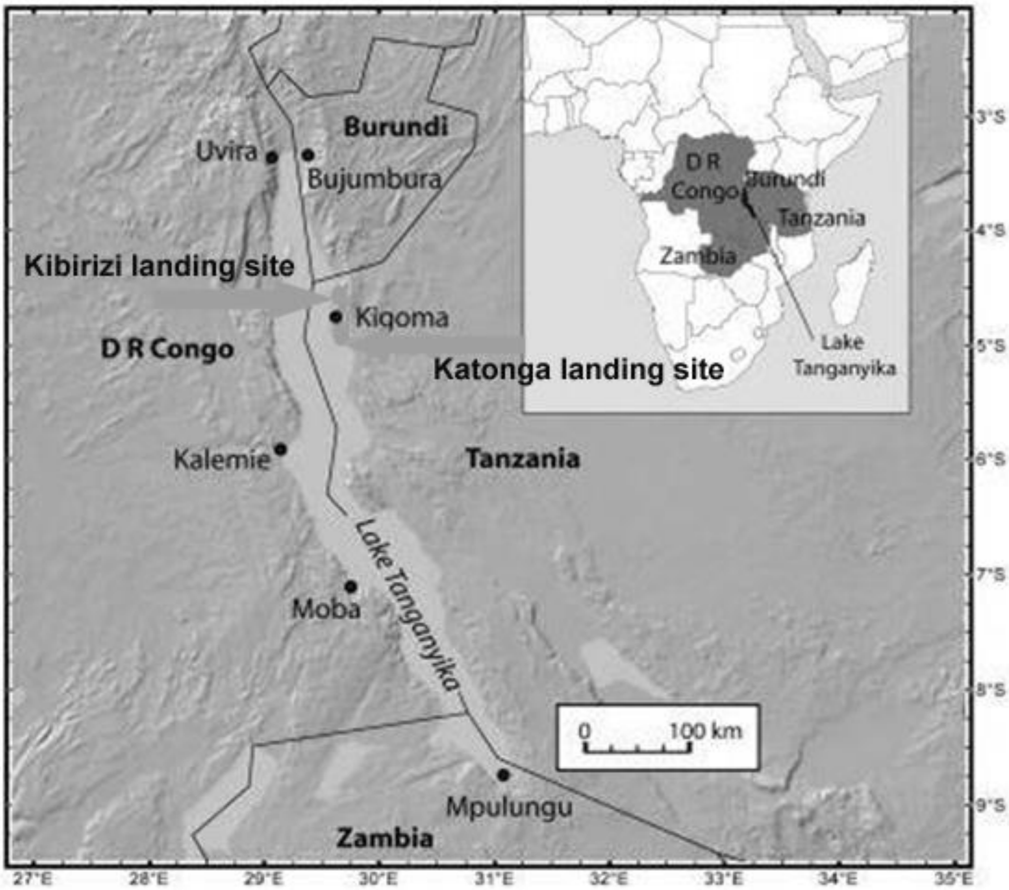

Figure 2.1: *Location of Katonga and Kibirizi Landing Sites*

People in and around the landing sites that were not directly engaged in fisheries, were engaged in indirect fisheries activities. These activities, among others, included: boat construction and repairing, trading in fish and sardines, trading in perishable goods during morning markets especially vegetable and tomatoes that was done mainly by women, restaurants and tailoring.

The location of the study areas with respect to Lake Victoria, were landing sites in Sengerema and Ilemela Districts in Mwanza Region. One landing site in each district was identified. In Sengerema, Kijiweni landing site was identified for the study and in Nyamagana, Igombe landing site was identified. These two landing sites are famous for Nile perch fisheries. The unit of analysis in landing sites was a camp composed of fishers who formed a fishing team that operated a fishing canoe. Each canoe was operated by four fishermen. The selection of fishermen for the interview was done at a random. The locations of the two landing sites are shown in Figure 2.2.

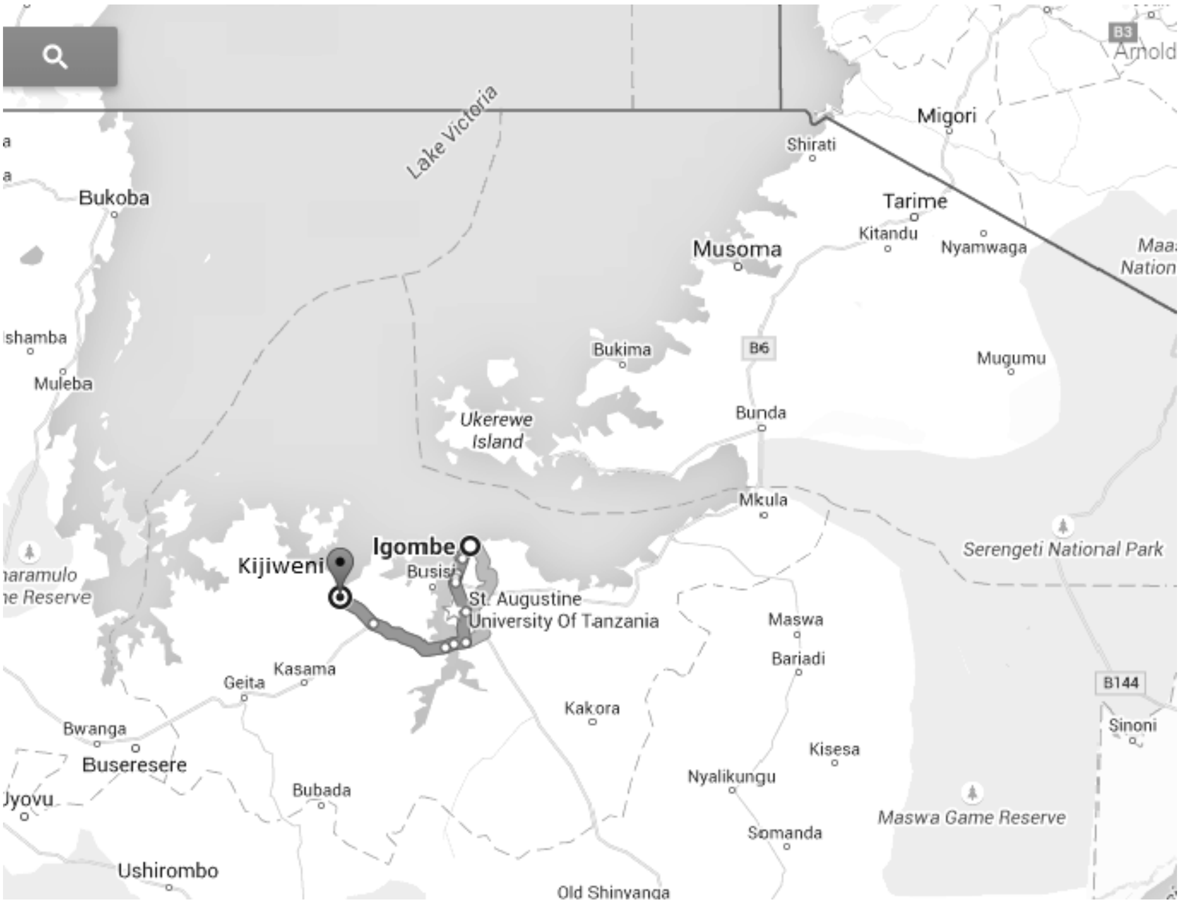

Figure 2.2: *Location of Kijweni and Igombe Landing Sites*

Participatory Methodology

Participatory Rural Appraisal (PRA) methodology was used. PRA method enables local communities to contribute their indigenous knowledge and experience, skills and labor in planning and implementing their activities that lead to the improvement in their livelihoods. Three types of data using PRA method were collected: *Spatial data*-that gave location and a view of community problems and opportunities. *Time related data*-that gave information on connections over time. *Social data*-that were collected through interviews regarding socio-economic activities that were being carried out in the fishing beaches (Landing site). An interesting characteristic of the PRA method is that it stresses the link between technical and socio-economic issues in defining problems and identifying solutions.

The PRA was implemented in a number of specific stages. These were site selection: the first step was to select the site where PRA would be carried out, preliminary visit by the PRA research team: this was done with the purpose of introducing the approach to the concerned community of fishers, data collocation: the third stage of PRA method was data collection. The types of

PRA methods that were employed by this study were mapping and modelling. These methods were used to map out key changes over time (on a year-to-year basis). They were used to show income-generation opportunities and any other sources of incomes in the fishing communities, time lines and trends. The methods were used to map out major changes in the fishing beaches. The techniques were useful in showing what has happened over time in a given period of time usually one year. Trends in the level of catches in different seasons where observed using this approach. For triangulation, three points of view were the basis of PRA using triangulation method, they included tools and techniques, which were the means by which information from the fishers were collected. The tools and techniques included observation of what took place in the landing sites and questionnaires; units of observation; which were the fishing breaches/landing sites. They were observed with a view to getting a clear picture of what was happening; team composition; which composed of field researchers. The team included insiders and outsiders.

RESULTS AND DISCUSSION

Characteristics of Lake Tanganyika Fishers

As shown in Table 3.1, of the 35 fishers 29 fishers, equivalent to 82.9 percent of the total fishers had attained primary education. The age group of fishers that was actively participating in fishing in the landing sites was in the range of 18–30 years that was equivalent to 48.6 percent of the total fishers. A fisher's household that had the largest number of children had 10, while that with the smallest number had 2 children.

Table 3.1 Characteristics of Lake Tanganyika fishers

Variable	Number/Frequency	Percent
Sex		
Male	35	100.0
Female	0	0.0
Total	**35**	**100.0**
Age groups		
18 – 30 years	17	48.6
31 – 40	14	40.0
41 – 50	4	11.4

Above 50 years	0	0.0
Total	**35**	**100.0**
Marital status		
Married	34	97.1
Single	3	2.9
Divorced	0	0.0
Total	**35**	**100.0**
Level of Education		
Primary Education	29	82.9
Secondary Education	4	11.4
Adult Education	2	5.7
Total	**35**	**100.0**

Source: *Field Survey 2013*

Characteristics of Lake Victoria Fishers

Table 3.2 shows characteristics of Lake Victoria fishers. All 53 fishers that were covered by this study were males and had attained primary education except for one respondent that had attained secondary education. This fact negates the views that were taken on board by Reynolds *et al* (1999) that local fishers lack primary school education. However, Reynolds *et al* (1999) is supported by the view held by this study that fishers are almost exclusively men and generally fall within the range of 18-50 years.

Table 3.2: Characteristics of Lake Victoria Fishers

Variable	Number/Frequency	Percent
Sex		
Male	53	100.0
Female	0	0.0
Total	**53**	**100.0**
Age groups		
18 – 30 years	27	50.9
31 – 40	23	43.4
41 – 50	3	5.7
Above 50 years	0	0.0
Total	**53**	**100.0**

Marital status		
Married	51	96.2
Single	2	3.8
Divorced	0	0.0
Total	**53**	**100.0**
Level of Education		
Primary Education	52	98.1
Secondary Education	1	1.9
Adult Education	0	0.0
Total	**53**	**100.0**

Source: *Field Survey 2013*

The age group of fishers that participated actively in fishing was in the range of 18–40 years that represented 94% of the total fishers.

Incomes Generated

Lake Tanganyika Fisheries

Table 3.3 indicates net monthly income accruing to fishers and fishing gear owners during high catch season (October-March). Fishing gear owners took the lion's share of the net income that was generated, but still fishers also netted relatively higher incomes during high catch season. The net income that was generated was either divided into three or two parts. For fishers in the three categories, the owner of the gear took two thirds and one third was shared equally by the four fishers that formed the fishing team. With the fifty-fifty percent case, the owner of the gear took half (fifty percent) of the net income that was generated and the other half was divided equally among the four fishers. A fisher who earned the highest monthly income netted $ 3,400 while one with lowest netted $ 600. The majority of fishers (17 fishers) each earned between $ 1875 and $ 3750[7].

With respect to fishing gear owners, the highest monthly income earner netted $ 13,750 while the lowest income earner netted $ 1500. Generally speaking, the gap between the income earned by fishers and gear owners was wide. One of the explanations to this scenario emanates from high production costs were incurred by fishers. Fishers bought on credit petrol and kerosene

[7] Note that the exchange rate of 1 US Dollar to Tanzanian Shilling was 1$=1600Tshs when the study on Lake Tanganyika fisheries was carried out and was 1$=1550Tshs when the study on Lake Victoria fisheries was conducted.

at an inflated price from gear owners[8]. But also the ratio that was used to divide the net income that was generated favoured the gear owners. To this end, gear owners realised profit before even the actual fishing was done.

[8] Variable costs, namely petrol and kerosene were relatively higher for fishers than for the gear owners. What took place on the ground was that gear owners secured petrol and kerosene from oil companies in Kigoma at a market rate price and sold the energy at a higher price to fishers on credit, with view to raising the money at the end of fishing season, usually at the end of dark-moon phase. Gear owners bought one litre of petrol at US$1.16 and were selling the very litre at US$ 1.38. Again, one litre of kerosene was bought at US$ 0.78 but was sold to fishers at a price between US$ 0.812 and US$ 0.84.

Table 3.3: Net Monthly Income Accrued to Fisher and Gear Owners during High Catch Season (in US $)

	Below 625	**625-1875**	**1875–3750**	**3751–5625**	**5625–7500**	**7501–9375**	**9376–11250**	**11251-13125**	**13126-15000**	**Total**
Fishers	1	16	18	-	-	-	-	-	-	**35**
Gear owners	-	1	4	3	4	-	1	-	2	**15**
Total	**1**	**17**	**22**	**3**	**4**	-	**1**	-	**2**	**50**

Source: Field survey 2013

Table 3.4: Net Monthly Income Accrued to Fisher and Gear Owners during Low Catch Season (in US $)

	-625 – 0	**1–625**	**626–1875**	**1876–3125**	**3126–4375**	**4376–5625**	**5626–6875**	**Above 6875**	**Total**
Fisher	5	29	1	-	-	-	-	-	**35**
Gear owner	4	2	3	2	1	-	1	2	**15**
Total	**9**	**29**	**4**	**2**	**1**	-	**1**	**2**	**50**

Source: *Field survey 2013*

Table 3.4 shows net monthly income earned by both fishers and fishing gear owners during low catch season (April-September). Generally, the incomes were far below not only for fishers but also for the fishing gear owners; of course, gear owners were relatively far better than their fisher counterparts. An interesting scenario is the 2 fishing gear owners that each netted monthly income that was above US$ 6,875. In fact, one gear owner netted US$ 12,250 and the other one netted US$ 17,625, which was over and above of the highest income that was generated during high catch season.

One of the explanations to this paradox could be that fishing gear owners might have secured good/high prices upon landing at the landing site. The income that was generated was not necessarily reflected by the quantity of fish that was caught but rather the prices that prevailed at the landing site when there was scarcity of fish.

To this end, one may be tempted to conclude that both fishers and gear owners create wealth during high catch season. However, due to the losses that they incur during low catch seasons, the impact of such created wealth is diluted. In the first place, fishers accumulate huge debts in low catch seasons and a fishing gear owner had no option of recovering his money invested in buying petrol and kerosene except waiting for a good/high season to come. It is during high catch season that a fishing gear owner recovered his accumulated debts.

Thus, the higher net monthly income generated by the fisher during high season does not necessarily reflect what he actually receives. The fisher is supposed to pass on accumulated debt to the fishing gear owner. Furthermore, it should also be noted that the higher incomes experienced during high catch season were not experienced during the entire period. Within the high season there are some variations in the level of catches.

Lake Victoria Fisheries

Tables 3.5 and 3.6 show incomes that were generated by fishers and fishing gear owners during high catch season and low catch season respectively. With respect to Table 3.5 which shows incomes that were generated by fishers and fishing gear owners during high catch season (May-November), it is evident that gear owners, although did not do the actual fishing task, took the lion's share of the incomes that were generated. The majority of fishers (35 fishers out of 53 fishers), each generated net monthly income that ranged between US$ 161 and US$ 480. However, 5 fishers each generated income that was below US$ 160; in fact, the lowest netted US$ 39. Of the 35 fishers that each generated net monthly income that ranged between US$ 161 and US$ 480, only 6 fishers operated their fishing activities at *Kijiweni* land site; the remaining 31 fishers operated their fishing activities at *Igombe* landing site. Furthermore, of the 5 fishers that each generated net monthly income below US$ 160, only 1 fisher originated from *Kijiweni* land site and the other 4 fishers originated from *Igombe* landing site. All best 5 fishers in terms of the incomes they generated, as per Table 3.5, operated their fishing activities at *Kijiweni* landing site; they each generated net monthly income above US$ 2,100. In fact; the highest income earner in this category generated as much as US$ 2,500.

Fishing gear owners generated more incomes than fishers. The majority of fishing gear owners (24 gear owners out of 53 gear owners) each generated net monthly income that ranged between US$ 1,131-1,450. Of the 24 fishing gear owners who were in the aforesaid income range only 3 of them operated their fishing activities at *Kijiweni* landing site and the rest (21 gear owners) operated their fishing activities at *Igombe* landing site. Fishing gear owners who generated net monthly incomes from US$ 1,451 and above operated their fishing activities at *Kijiweni* landing site. The 2 fishing gear owners that each generated above US$ 2,100, one netted 2,350 and the other one netted US$ 2,450.

The reason behind good performance in terms of income generation by the fishers *in Kijiweni* landing site was mainly because of three factors, *first*, fishermen used man-powered canoe that did not use petrol[9] that was very expensive, *secondly*, fishermen at *Kijiweni* used hooks that were cheaper than gill-nets, and *thirdly*, the owner of fishing gear was one among the four fishers that composed the fishing team and experienced the nature of the fishing task that demanded energy and risks, and therefore allowed a fair deal in distributing the income that was generated. The owners of fishing gear at *Igombe* landing site-in Ilemela district did not participate in fishing and their canoes were engine-powered that used petrol that was very expensive and thus reduced net income that was generated. They further used gill-nets that were very expensive as opposed to hooks that were cheaper.

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[9] However, 5 out of 20 fishers at Kijiweni beach were using engine-powered canoes that used petrol for patrolling areas occupied by hooks. They used man-powered canoes to and fro fishing only.

Table 3.6 shows net monthly incomes that were generated during low catch seasons (December-April). Incomes were far below from those generated during high catch seasons. However, fishing gear owners were relatively far better than fishers. Out of 53 fishers, 46 fishers each generated income below US$ 160; in fact half of the 46 fishers each generated net monthly income amounting to US$ 40. Again, fishers and gears owners that performed relatively well operated their fishing activities at *Kijiweni* land site for the reasons mentioned above.

Table 3.5: Net Monthly Income Accrued to Fisher and Gear Owners during High Catch Season (in US $)

	Below 160	**160–480**	**481–800**	**801–1130**	**1131–1450**	**1451–1775**	**1776–2100**	**Above 2100**	**Total**
Fishers	5	35	4	1	2	1	-	5	**53**
Gear owner	1	7	12	2	24	2	3	2	**53**
Total	**6**	**42**	**16**	**3**	**26**	**3**	**3**	**7**	**106**

Source: *Filed survey data, 2013*

Table 3.6: Net Monthly Income Accrued to Fisher and Gear Owners during Low Catch Season (in US $)

	Below 160	**160–480**	**481–800**	**801–1130**	**1131–1450**	**1451–1775**	**1776–2100**	**Above 2100**	**Total**
Fishers	46	7		-	-	-	-	-	**53**
Gear owners	28	23	1	-	1	-	-	-	**53**
Total	**74**	**30**	**1**	-	**1**	-	-	-	**106**

Source: *Filed survey data, 2013*

Implications of the Incomes Generated on Pro-Poor Growth

The implication of the incomes that were generated has to do with incomes that were generated by both fishers and fishing gear owners. During high catch season, fishers generate higher incomes; however, during low catch season the situation is reversed. Since both high and low seasons are of equal length i.e. six months each, money generated during high season compensates for low incomes in low catch season. Part of the money generated by fishers during high season was used to pay for the accumulated debts in low catch season, which reduced their disposable income. Generally, in absolute terms, Lake Victoria fishers and fishing gear owners were far below in terms of the incomes they generated compared with fishers and fishing gear owners that operated their fishing activities at Lake Tanganyika.

Expenditure Pattern of the Incomes Generated by Fishers

Fishers spent their incomes from fisheries mostly on food, followed by medication and house construction. Although fishers had large families (for Lake Tanganyika fishers), they did not indicate that they were paying school fees and other associated school costs for their children. As to whether the incomes from fisheries had impact on pro-poor growth, all fishers that operated their activities at Lake Tanganyika admitted that incomes from fisheries were helping them to improve their welfare.

The same views were held by fishers that operated their activities at Lake Victoria on the expenditure pattern. All fishers spent part of the incomes generated on food; they also reported to pay school fees for their children. Nevertheless, they were unsatisfied with the income accrued to them that was very meagre. This was particular true for fishers that operated their fishing activities at *Igombe* landing site. Fishers that operated their fishing activities at *Kijiweni* landing site had a different view. Of the 20 *Kijiweni* fishers, only 5 fishers reported that their incomes generated were meagre. But it should further be note that 33 out 53 fishers reported to have spent money on alcohol and 31 out 53 fishers reported to spent money on prostitution. Surprisingly none of the fishers that operated fishing activities at Lake Tanganyika reported to have spent money on alcohol and prostitution. This implies that for those fishers that spent money on alcohol and prostitution were not directing those resources to pro-poor growth related activities/services. To this end, such fishers can hardly accept that the incomes generated from fisheries can lead to pro-poor growth.

Expenditure Pattern of the Incomes Generated by Fishing Gear Owners

Lake Tanganyika fishing gear owners did not clearly indicate as to where the money generated was directed to. Fishing gear owners were not ready to report as to where they re-invest the money generated from fisheries. They however pointed out that the money generated during high catch season compensated for the meagre incomes generated during low catch season.

Nevertheless, fishers pointed out that fishing gear owners kept on re-investing in fisheries by constructing new fishing canoes and buying other related fishing gears. At this juncture, it should be noted that in fishing communities in Kigoma region, a fishing gear owner was respected if he owned many fishing boats. This assertion explains where the incomes generated by gear owners were directed to. But this had a risk as discussed under the challenges facing Lake Tanganyika fisheries.

With respect to Lake Victoria fishing gear owners in terms of how they spent money that was generated; it was a different scenario all together. For them, they did re-invest in other diversifications such as houses' construction and opening up whole sale and retail shops.

Challenges of Lake Tanganyika and Lake Victoria Fisheries

Lake Tanganyika Fisheries Challenges

Both fishers and owners of the fishing gears raised challenges that compromised Lake Tanganyika fisheries. These challenges include but not limited to:

Piracy: gear owners and fishers had serious concerns that piracy incidents were increasing at an alarming rate and felt that the government was doing very little to protect them while fishing. Fishers were the hardest hit since they risked their lives. Pirates came from the neighbouring countries and had rendered many fishing gear owners property less. Pirates went away with all the fishing gears, once they seized the fishing boat.

Rising prices of fishing gears: this was also another challenge facing Lake Tanganyika fisheries. The cost of starting fishery business was too high for an ordinary fisher to start his own business. It costs US$ 8,750 to start the fishing business with just a catamaran. This was a huge amount of money that could hardly be raised by an ordinary fisher.

Inflated prices of petrol and paraffin: fishers were of the view that owners of fishing gears were not giving practising a fair deal. They bought petrol and kerosene at a market rate price but sold to them at inflated prices. The cost of petrol and kerosene was recovered at end of dark-moon phase was born by the fishers and not by the gear owners.

Unequal income distribution: the formula that was used to distribute income that was generated between fishers and fishing gear owners was unfair. Fishers were primarily the generator of the incomes but ended up getting very little of what they generated.

Lake Victoria Fisheries Challenges

Fishers that operated their fishing activities at Lake Victoria reported the following challenges:

Poor payment systems: fishers had different ways through which they received their monthly payments. Some payment systems were very exploitative in nature and did not let the fishers feel as if they were part of the business they operate. Some fishers were given a fixed monthly salary of around US$ 39 while others were given days in a month to fish for themselves. Depending on the bargaining power of fishers, the days ranged from 2 to 4.

Lack of social security: although lack of social security was not reported by Lake Tanganyika fishers, it was a major challenge to Lake Victoria fishers. They reported to have no formal contracts with owners of the fishing gears. The owner of the fishing gears could fire off any fisher if he felt it. Fishers reported that they had no social security because they had no contracts that could guarantee security upon termination of their contacts. With contract, the owner of the fishing gear could be forced to remit funds to the pension fund that could assist a fisher upon termination of the contract.

The whole issue of safety during fishing: of all the fishermen, none had life-saving jacket and this risked the lives of fishers. This issue was not reported by Lake Tanganyika fishers to be the challenge, although they lacked the same. Of course, security concerns were also raised by Lake Victoria fishers.

Diseases in the landing sites: there was a wide-spread of diseases in the landing sites such typhoid and bilharzias that were attributed to the destruction of environment in the landing sites. Unlike Lake Tanganyika landing sites, Lake Victoria landing sites were polluted places and the local government seemed to have over-looked the environmental concerns in the landing sites.

Over-fishing*:* This was indeed among the major challenges that were reported by all fishers. This came out clearly when respondents were asked on the size and availability of Nile perch. Their answer was the sizes of Nile perch that were caught were small and the type of fish was not readily available.

CONCLUSION AND POLICY IMPLICATIONS

CONCLUSION

This study has gone a long way to show the extent to which Lake Tanganyika and Lake Victoria fisheries is for pro-poor growth. Indeed, fisheries in both lakes can lead to pro-poor growth if well managed and based on a *win-win* scenario. As it has been noted, owners of the fishing gear took the lion's share of the incomes that were generated by fishers. Fishers who did the actual fishing work ended up getting less than what the gear owners netted. This was true for both Lake Tanganyika and Lake Victoria fishers. Although both fishers and fishing gear owners that operated their fishing activities at Lake Tanganyika were absolutely better than their counterparts at Lake Victoria, the *win-win* scenario was still a paradox. The income gap between fishing gear owners and fishers was so pronounced. To that effect, pro-poor growth scenario can hardly be sustained since fishers (the poor) are perpetually being exploited.

As to the expenditure pattern of Lake Tanganyika fishers, the pattern was mixed though spending on food occupied a central place. Gear owners who took the lion's share of the incomes generated did not clearly indicate as to where the incomes generated were directed to. They were not ready to report as to where they invested the money generated from fisheries. However, fishers pointed that owners of the fishing gear were investing the money generated by buying more fishing gears.

With Lake Victoria fishers, their consumption pattern was also mixed though the income that was spent food occupied a central place. Furthermore, fishers also reported to have spent money generated from fisheries on school fees, house construction, and medical expenses. Despite the fact that none of the fishers that operated fishing activities at Lake Tanganyika reported to have spent money on alcohol and prostitution; fishers that operated their fishing activities at Lake Victoria reported to have spent money on alcohol and prostitution. In fact, at least 31 fishers out of 53 fishers reported to have spent part of their incomes on alcohol and prostitution. To this end, pro-poor growth can hardly be sustained by fishers of that kind of behaviour.

Policy Implications

Policy options arising from this study should focus on how to mitigate challenges facing fisheries activities in the two lakes. To this end, issues that attention should be paid should include:

Curbing incidences of piracy: fishers and fishing gear owners were affected by incidences of piracy. Their efforts to expand fisheries business were compromised by the incidences of piracy. There was an urgent need to curb the incidences. The incidences of pirates were common in both lakes although they were more pronounced in Lake Tanganyika than in Lake Victoria.

Diversification of investments: fishing gear owners generated a lot of money during high catch season, which could be invested in other productive investments. An attractive investment climate apart from fishing was vital not only for Lake Tanganyika fishing gear owners but also for Lake Victoria fishing gears owners. This could reduce the high risks of a rich fishing gear owner falling into poverty once his fishing gears are confiscated by pirates.

A balanced win-win fisheries business: There was a need for local governments both in Kigoma municipal and Mwanza city councils to intervene on the issue of inflated prices of petrol and kerosene. Fishers were forced by their fishing gear owners to buy petrol and kerosene at inflated rates. Fishing gear owners bought the two items at market rates from oil dealers and sold to their fishers on credit at inflated prices. Along with the balanced *win-win solution*, there was the whole issue of accessing capital. Fishing gears were very expensive and fishers could hardly afford them unless credits or subsidies were granted with view to assisting fishers purchase the gears.

Collection of taxes: putting in place strategies that could enable the local government to collect taxes from gear owners. Gear owners were not paying tax to the government on a pretext that they were making losses. The only tax they paid was the licence tax that was paid once in a year. The challenge that was facing the local government was to establish the level of incomes that were generated by fishing gear owners due to nature of the marketing system that prevailed in the landing sites. The marketing system was complicated because the catches were sold to middlemen early in the morning before local government officials arrived at the landing sites. This was particularly true for Lake Tanganyika fisheries.

The whole issue of safety during fishing: all the fishers in both lakes; none had life-saving jacket. This was indeed a high risk for fishers given the nature of the lakes that experienced frequent storms. The local governments should over-see this problem and come up with solution. Before the canoes (fishing boats) are allowed to operate, the owners of the fishing gears should prove beyond reasonable doubt that they have all the requirements, including but not limited to life-saving jackets.

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ASSESSMENT OF SURFACE WATER QUALITY ALONG THE LOLIONDO GAME CONTROLLED AREA (LGCA) SEGMENT OF THE PROPOSED HIGHWAY THROUGH SERENGETI NATIONAL PARK, TANZANIA

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ABSTRACT

Water quality assessment was carried on several rivers and streams along the proposed Serengeti-Mto wa Mbu all-weather road from Wasso village to Klien's Gate between December 2012 and May 2013. Some physico-chemical water parameters (turbidity, pH, alkalinity, temperature, conductivity, total dissolved solids) were measured in-situ using a water quality water sampler SensION156 portable multi-parameter meter. Water samples were also collected using a standard vertical water sampler by dipping it just below the surface at the center of the river and taken to the Chemistry Department, University of Dar es salaam (UDSM) for analysis. The physico-chemical analysis of the water samples was carried out following standard methods, mainly TZS 574:2002 method of test for the quality of drinking water. The physico-chemical parameters determined at UDSM laboratory were Biological and Chemical Oxygen demand, hardness, total suspended solids, nitrate, nitrite, fluoride, phosphate, sulfate, chloride, ammonium, sodium, potassium, calcium levels as well as heavy metals cadmium, chromium, copper, iron, manganese and lead. The results indicated that the waters from the natural surface sources were normal, safe and acceptable for animal and human use. However, the waters need to be treated in order to improve water clarity before use as drinking water as well as to avoid infection as biological analysis was not conducted during the current study.

Keywords: Conservation, IPBES, Serengeti ecosystem, water quality, wildlife management

INTRODUCTION

It is a well known fact that water is essential to life and therefore a reliable, secure, safe, and sufficient source of fresh water is a fundamental requirement for the survival, well-being, and development of all forms of life including humans (Tebbutt, 1990). A safe water resource should provide water that is clear, colourless, tasteless, odourless with no suspended matter or turbidity and lacking heavy metals and other ions. Rivers and streams are also vulnerable freshwater ecosystems that are critical for the sustenance of all life.

Under the 'Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) project, one of the goals was to establish baseline data for studying and understanding the dynamics of the proposed road construction of the northern Serengeti highway to the conservation of the Serengeti and Ngorongoro districts' ecosystem and any socio-economic trade-offs. It is predicted that with the new highway, increased human population and motor traffic will transverse the area, generally leading to a disturbing influence on the people, animals, vegetation, biodiversity and the environment including surface water sources in the area. The study area of this report is the proposed road segment to the east of the Serengeti National Park within the Loliondo Game Controlled Area (LGCA). As baseline information before road construction, the research team has assessed the status and quality of the surface water sources (rivers and streams) close to villages along the proposed road within the LGCA. The parameters determined to assess surface water quality were: flow rate, turbidity, pH, alkalinity, temperature, conductivity, total dissolved solids, total suspended solids, hardness, nitrate, nitrite, sulphate, phosphate, chloride, ammonium, K, Na, Mg and several heavy metals. This information will not only be a useful tool for ecological assessment and monitoring of the quality of the water but will be used to compare with the results of the situation during and after the construction of the proposed road.

MATERIALS AND METHODS

Study area

The proposed Serengeti highway is administratively located in both Arusha and Mara regions. The study sites, along the north-eastern segment of the proposed highway, (Figure 1), lies within the LGCA. The sites were located at 0 km, 10 km and 20 km from the proposed highway to predict the likely impact of the project on water quality and quantity. Surface water sources close to Digodigo, Enguserosambu, Maaloni, Oloipiri and Ololosokwan villages in the LGCA were sampled. The water sampling sites and their distances from the proposed road are presented in Table 1.

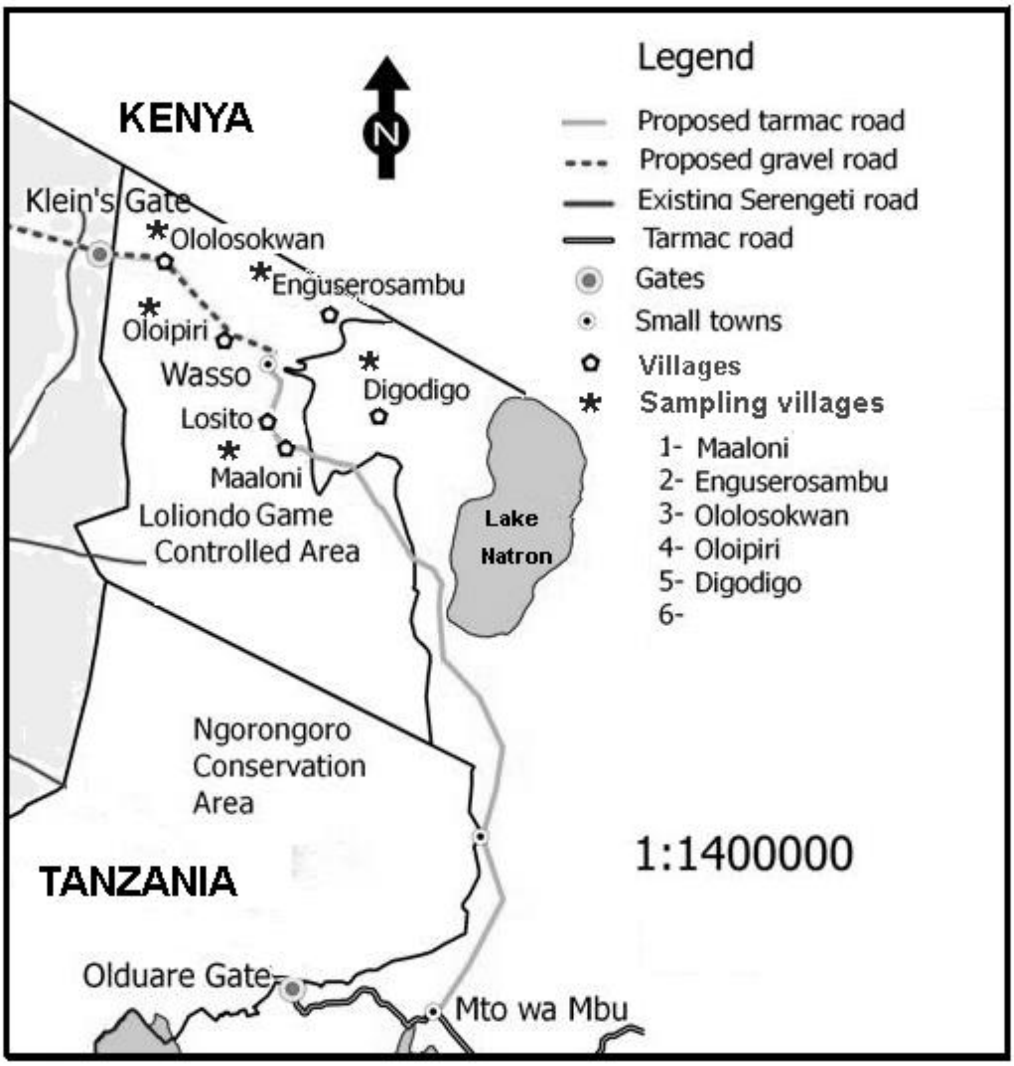

Figure 1: *The study area adapted from Røskaft et al. (2012)*

Table 1: Water sampling sites and distance from proposed highway [Geographical coordinates are in UTM system zone 36 South]

SN	Village	Sampling site /rivers/streams	Distance from proposed highway (km)	Village	UTM Eastings	UTM Northings
1	Ololosokwan	Isinyaa stream	0	Ololosokwan	759724	9792406
2	Ololosokwan	Mbilikiri stream	0	Ololosokwan	754427	9790428
3	Enguserosambu	Kingorama river	10	Enguserosambu	796728	9778244
4	Oloipiri	Poloret river	20	Oloipiri	769553	9776338
5	Maaloni	Maaloni stream	0	Maaloni	784058	9767436
6	Digodigo	Gheeri river	20	Digodigo	804572	9762612

Sampling sites characteristics

Isinyaa and Mbilikiri streams pass through Ololosokwan village (Figure 2). In Ololosokwan the waters are surrounded by mixed grassland, woodland and shrubs and the water is used for humans, livestock and wildlife. Water sampling was conducted just along the new road. At Enguserosambu, the Kingorama river (Figure 3), is covered by thick vegetation mixed with large trees. Agriculture is practiced near the area. Water sampling was conducted at a 10 km point from the new road. The site is a forested area and the river crosses the main road to Enguserosambu village. Cattle usually cross and drink from the river water.

Figure 2: *Isinyaa stream (Ololosokwan)* ***Figure 3***. *Kingorama river (Enguserosambu)*

The Digodigo water sampling site is located on Gheeri River (Fig. 4) on a 20 km point away from the new road. Gheeri River is used as a control site. Digodigo has grassland and woodland areas having areas covered by forest. Agriculture is the major activity especially irrigation farming. The river passes through the village settlement area. As you follow the river, the surroundings close to the river are covered with heavy bushes and green vegetation (Figure 4). At Maaloni village runs the Maaloni river. The area around Maaloni river has mainly trees, grassland and shrubs of various species. The river water at this location is mainly used by humans, livestock and wildlife. Water sampling was conducted just alongside the proposed road. Along Poloret River at Oloipiri the areas are covered with grassland mixed with shrubs. Near the river there are some cultivation activities taking place. The grassland and scrubby areas were mainly used by cattle as grazing areas. This water sampling site, at 20 km point from the new road, is also used as a control.

Sampling and determination

On-site measurements and collection of water samples was conducted between December 2012 and January 2013 and in April/May 2013. Water samples were collected using a standard vertical water sampler by dipping it 5 – 10 cms below the surface at the center of the river or stream (Kaswamila *et al.* 2014). While on-site measurements of physicochemical parameters were conducted using a SensION156 multi-parameter meter. The collected water samples were then stored in 1 litre sterilized bottles and sent to the Chemistry laboratory at the University of Dar es Salaam. Flow rate were determined using a floater method. The physico-chemical analysis of the water samples was carried out following standard methods, mainly AWWA (1998) and TZS 574:2002 method of test for drinking water quality (TBS). Water clarity was measured using a Secchi disk (2.5 cm size). A nephelometer was used for measuring water turbidity. The standards of WHO and Tanzania Bureau of Standards (TBS) were used in comparing the results.

***Figure 4*:**. *Gheeri river (Digodigo)*

RESULTS AND DISCUSSION

The results of the measurement on the water samples are presented in Table 2 and 3. The flow rates of the waters were generally low as all the sampling sites recorded less than a digit value (Table 2). These rivers/streams had low flow rates in the dry season but will most certainly have higher flow rates during the wet season.

Secchi depth results (2 m to clear) suggest that water clarity of all the sampled rivers and streams were very good. It has been reported that the greater the secchi depth measurement (up to 40 m), the clearer the water bodies (Jidauna *et al*. 2013). The reasons for the high water clarity could be that there is lack of suspended sediments in the waters as water clarity primarily arises due to lack of algae growth and suspended sediments (http://who.int).

As for water temperature, the sampled water sources were found to have acceptable temperatures, as per WHO guidelines. Day water temperatures ranged between 19.4° C and 29.1° C. All pH values for the river/stream waters were between 7.0 and 7.7. The lower the pH (< 7) the more corrosive water will be. However there are no known health implications associated to pH (tttp://wateraid.org). While extreme pH values (<4 and > 11) may adversely affect health, it is argued that <pH 6.5 may be corrosive while pH 8 progressively decreases efficiency of chlorination and pH > 8.5 may cause scale and taste problems (Olszowy 2010). The World Health Organization has set the range of 6.5 to 8.5 as a suitable guide level for pH of drinking water. The electrical conductivity (EC) value gives an estimation of the total dissolved salts or salinity in the waters. The EC range of 83 to 583 µS cm^{-1} measured is acceptable for potable water. Levels up to 800 µS cm^{-1} are acceptable in drinking water (WHO). For health purposes drinking water should not have very high EC as it is related to the concentration of ions originating from inorganic compounds (Sherif 2010).

The total hardness levels of the water i.e. the amount of calcium and magnesium ions in water, ranged between 26 mg/L and 74 mg/L. Values near 150 mg/L are generally ideal from an aesthetic view point (Sherif 2010). Water with < 150 mg/L is considered soft water while water with values > 200 are considered hard water.

The nitrate level of the waters in the study area was low when compared to the national and WHO standards. The values recorded were from 1.2 to 2.24 mg/L. Nitrates are regulated in drinking water primarily because excess levels can cause methemoglobinemia, or blue baby disease (Fan *et al*. 1987, Sadeq *et al*. 2008). Infants < 6 months of age and pregnant women should avoid and not drink water that contains levels of nitrate-nitrogen >10 mg/L (Kross *et al*. 1992). The nitrite levels of the waters were also very low. Nitrite-nitrogen MCL level is 1.0 mg/l. Infants < 6 months of age who drink water containing nitrite in excess of the MCL could become seriously ill, develop blue baby disease and may die (EPA).

Calcium levels in the rivers/streams ranged between 5.7 mg/L and 45.1 mg/L. These values are well within the national and WHO acceptable limits and are therefore safe levels. Levels between 20 to 30 mg/L are desirable in drinking water. The TDS values were also low, ranging from 62.1 mg/L to 306 mg/L. The waters maybe classified as low mineral content waters. There is no health related guideline value for TDS. However, for aesthetic reasons (taste) the concentration of TDS in drinking water should not exceed 500 mg/L (WHO). Up to 1000 mg/L may be acceptable depending on taste. Turbidity values were higher than the acceptable national and WHO standards. The values ranged between 27 and 762 NTU. These values are too high when compared with the recommended WHO standard of 5 NTU. Turbidity occurs as a result of a suspension of fine colloidal particles that do not readily settle out of solution and can result in cloudiness. Turbidity in water is more of an aesthetic contaminant than a health problem. Turbidity values for aesthetic reasons should be <5 NTU (WHO) and <25 NTU (TBS).

Chloride levels (68.2 – 167.8 mg/L) indicate low concentration of chloride when compared to an acceptable level of up to 400 mg/L (WHO). Chloride is not toxic, but some people can detect a salty test when high levels of chloride are present. Water with high chloride may also have elevated sodium content. Chloride has no health standard. Levels <10 mg/L are desirable. Levels > 250 mg/L may cause a salty taste or corrosion of some metals. There is no health related guideline value for chloride however for aesthetic reasons (taste) water should not exceed 250 mg/L. Chloride occurs naturally in waters with dissolved minerals and salt. As far as heavy metals (Fe, Mn, Cu, Cd, Pb and Cr) were concerned, the rivers and streams along the proposed road were safe as the levels were well below the detection limit of 0.001 mg/L.

Table 2. Water quality of surface waters along the proposed road segment within the Loliondo Game Controlled Area during the dry season (December 2012/January 2013) Rivers and streams (Village)

Parameter	Isinyaa (Ololosokwan)	Mbilikiri (Ololosokwan)	Kingarama (Enguserosambu)	Poloret (Oloipiri)	Maaloni (Maaloni)	Gheeri (Digodigo)	TBS standards	WHO guide values
Temp.(°C)	22.6	20.3	19.4	19.8	29.1	28.0	19 - 35	29
pH	7.56	7.38	7.19	7.47	7.65	7.47	6.5 – 9.2	6.5 – 8.5
DO (mg/L)	7.2	6.6	9.22	7.43	5.51	6.08		
Salinity (ppt)	0.15	0.07	0.08	0.10	0.43	0.16	1.0	0.5
Flow rate (m^3s^{-1})	0.15	0.02	0.01	0.23	0.02	0.21	NA	NA
Secchi depth (m)	2.5	Clear	Clear	2	2	Clear		>40

EC (µS cm^{-1})	141.8	126.9	83.2	299	583	283	2000	800
TDS mg/L)	74.6	62.1	47.4	160.1	306	136.4	1000	500
TSS mg/L	68	66	17	594	257	18	200	
Turbidity (NTU)	79	64	27	762	339	33	25	5
TH mg/L	26	16	28	58	74	68	600	150
BOD mg/L	10.08	9.96	1.83	8.94	1.07	4.96	6.0	NA
COD mg/L	104.0	124.8	145.6	208.0	62.4	83.2		NA
ANIONS (mg/L)								
NO_3	1.602	2.161	1.255	1.242	2.201	1.320	75	50
NO_2	0.001	0.001	Nil	0.001	Nil	0.049		3
Cl	71.9	68.2	70.1	99.6	167.8	81.1	800	400
PO_4	0.253	0.026	0.024	0.420	0.411	0.041		1.0
SO_4	12.2	6.3	13.4	11.8	5.5	21.4	600	200
CATIONS (mg/L)								
NH_4	0.042	0.024	0.022	0.011	0.034	0.023	2.0	
Ca	16.1	5.7	8.7	41.4	45.1	21.1	100	75
Fe, Mn, Cu	BDL	BDL	BDL	BDL	BDL	BDL		0.05
Cd, Cr, Pb	BDL	BDL	BDL	BDL	BDL	BDL		0.005

BDL ≤ 0.001 mg/L, TH – Hardness, NA – Not Applicable, DO – Dissolved Oxygen, Temp - temperature

Table 3: Water quality of surface waters along the proposed road segment within the Loliondo Game Controlled Area during the wet season (April/May 2013)

Parameter	Ololosokwan-Mbirikiri stream	Ololosokwan-Isinya a stream	Enguserosambu Kingorama river	Digodigo - Gheeri river	TBS	WHO
Colour	363	254	251	162	50	
Temperatur (°C)	20.3	22.6	19.4	28.0	19 - 35	
pH	7.06	7.22	6.59	7.36	6.5-9.2	6.5-8.5
EC ($\mu S\ cm^{-1}$)	137.9	172.7	51.8	242	2000	800
TSS (mg/L)	60	22	35	BDL	200	
TDS (mg/L))	63	79	24	111	1000	500
Turbidity (NTU)	72	26	44	1	25	5
TH (mg/L)	16	66	40	84	600	150
TA (mg/L)	76	80	40	122		120
BOD	1.29	2.76	1.09	1.77	6.0	
COD	30.4	30.4	101.2	101.4		
ANIONS						
NO_3 (mg/L)	49.17	41.62	19.73	22.13	75	50
NO_2 (mg/L)	0.596	0.528	0.324	0.885		3
NH_4 (mg/L)	1.617	1.043	3.039	0.721	2.0	0.3
PO_4 (mg/L)	0.27	0.49	0.462	0.288		1.0
Cl (mg/L)	38.6	58.1	81.0	73.6	800	250
SO_4 (mg/L)	4.93	4.65	4.19	4.17	600	500
CATIONS						
Na	21.67	65.75	0.34	24.23		50

(mg/L)						
Ca (mg/L)	2.01	6.87	1.13	10.89	100	
Si (mg/L)	12.32	6.84	3.37	4.67		
K (mg/L)	6.39	28.98	9.18	14.95		
Fe (mg/L)	1.05	1.10	0.38	0.077	1.0	5.0
Mn (mg/L)	0.032	0.019	0.024	0.016	0.5	0.5
Cu (mg/L)	0.02	BDL	0.009	0.032	3.0	2.0
Cd (mg/L)	BDL	BDL	BDL	BDL	0.005	0.003
Cr (mg/L)	BDL	BDL	BDL	BDL	0.05	0.05
Pb (mg/L)	BDL	BDL	BDL	BDL	0.1	0.01

TH - Total Hardness, TA – Total Alkalinity, EC – Electrical Conductivity, TDS – Total Dissolved Solids,

BDL - < 0.001 mg/L

CONCLUSION AND RECOMMENDATIONS

Flow rates of most rivers and/or streams before the construction of the highway were very low ranging from 0.01 to 0.23 m^3s^{-1}. The measured physicochemical parameters which were within the acceptable limits as per the national and WHO standards were temperature, EC, hardness, calcium, chloride and nitrate and TDS. Only turbidity levels were found to be higher than the WHO guide-levels. Therefore, the waters definitely require treatment for drinking water quality improvement. In general, most physicochemical characteristics of the waters in the study area justify the waters to be suitable for use by both humans and animals but for drinking water purposes the waters should be treated to remove the high levels of turbidity and suspended solids.

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CHALLENGES AND OPPORTUNITIES FOR SUSTAINABLE BEEKEEPING IN MIOMBO WOODLAND OF MLELE DISTRICT, WESTERN TANZANIA

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ABSTRACT

Beekeeping is an activity that provides livelihood opportunities for a considerable number of local communities in Tanzania. This study was conducted in Inyonga Division of Mlele District, Katavi Region July 2014. The area is recognized as among the higher potential areas for honey production in the Miombo Woodlands. The study aimed at assessing challenges and opportunities for sustainable beekeeping among the rural communities. Participatory Questionnaire Survey, Focus Group Discussion and Key Informant Interviews were used during data collection. A total of 101 beekeepers were interviewed from purposively selected three villages. Results indicated that traditional beekeeping is widely used in the area with bark hives being highly used (63%, n=11,928). Key identified challenges were, lack of beekeeping equipment (20.4%, n=101), prolonged droughts (14%), unreliable market and price fluctuation (8.9%), long distances to bee apiaries (8.9%) and lack of enough capital (7.2%). Tree cutting, tree debarking, use of fire during honey harvesting were reported as major cause of loss of both flora and fauna species that also limit beekeeping in the area. Main opportunities included presence of beekeeping groups, 101 beekeepers who responded, 91.4% belonged to beekeeping groups. Other opportunities observed were; Government willingness to support beekeepers, market availability, availability of skilled beekeepers and presence of extensive miombo woodlands. The study thus concluded that, though there are many challenges, however with the existing opportunities, the area can still produce more bee products if identified opportunities are fully utilized and sustainable beekeeping is promoted.

Key words: Beekeeping, Challenges, Opportunities, Livelihoods, Mlele District

INTRODUCTION

Sustainable beekeeping has been identified as an important economic activity that brings direct incentive to rural communities residing adjacent protected areas, it also promotes the conservation of biodiversity in a given ecosystem (Gemeda, 2014). Beekeeping supports livelihoods of rural communities in many ways (Mwakatobe and Machumu, 2011). When done appropriately, beekeeping provides significant reliable income for majority of marginalized farmers thus, it is considered to be an important part of livelihoods to forest dependent people in many developing countries (Mapolu, 2005; FAO, 2009; Qaiser *et al.,* 2013). Sustainable beekeeping in many developing countries has been recognized as among the best forms of sustainable agriculture practices that can improve livelihood of poor farming communities without much investment cost. It contributes significantly in nature preservation and support agricultural production through pollination process. In Tanzania, beekeeping contributes up to 33% of household income in the miombo woodlands (Monela *et al.,* 2000).

Tanzania has increased honey production from 4,860 tons (2001) to 9,380 tons in 2012 worth USD 9.38 million (Mkamba, 2012). The amount of beeswax produced has also increased from 324 tons (2001) to 625.3 tons in 2012 worth US$ 1.9 million (Mkamba, 2012). This production has contributed greatly to the country's economy. With this potential, Tanzania has recognized beekeeping as one of the important forms of sustainable agriculture (MNRT, 1998).

Elsewhere in Africa, beekeeping is regarded as an exceptional sustainable farming for people to earn an income without damaging the environment (MNRT, 1998). Beekeeping activity is highly considered as an important environmental friendly activity that fits well in rural societies residing near forests.

Tanzania is endowed with favorable environment for the production of bee products (MNRT, 2007). The Miombo and Acacia woodlands, which are found throughout the country, are ideal for beekeeping industry (MNRT, 2007). Mlele District has been recognized as among the higher potential areas for honey production in the miombo woodlands (Mwakatobe and Machumu, 2011). The Regional records indicated that in 2009 there were about 6,200 beekeepers, having 3,260 modern hives and 344,500 traditional hives (log and bark hives (DNRO, 2014). The area is rich in forest reserves that cover about 2,801,169 (ha), 59 % of its total land area (4,584,300 Ha). From district records, these forests are under different protection categories and they form an important area for beekeeping investment.

Despite the rich forests and its higher potential in honey production, there are still some limitations in terms of quality and quantity of bee products in the area. Major challenges of beekeeping in the area are yet to be assessed. This study thus aimed at assessing the key challenges and opportunities for sustainable beekeeping in Mlele District. The findings from this study provide important information and feasible recommendations for future sustainable beekeeping in the area. The study specifically aimed at:-

- Assessing types of bee hives used.
- Assessing harvesting and processing methods of bee products.
- Identify main challenges of beekeeping practices in the study area.
- Identifying existing opportunities for local community's engagement in beekeeping industry.

METHODOLOGY

Study area

The study was conducted in Inyonga Division of Mlele District in Katavi Region. Inyonga, is the center of Mlele District which is located in the eastern part of Katavi Region (Figure 1) covering an area of 30,787.2 sq.km. The area is characterized by unimodal type of rain fall that starts from November to April with mean annual rainfall ranging from 920mm to 1,200mm and the average temperature ranging between 26°C and 30°C annually. The district has a population size of 282,568, of which 139,980 are males and 142,588 females, with average household size of 5.8 (URT, 2012). The main economic activities in the area are; farming, hunting, fishing, livestock keeping, lumbering and beekeeping. The main local economy relies on the cultivation of maize and beans as food crops while groundnuts, tobacco and honey as major cash crops.

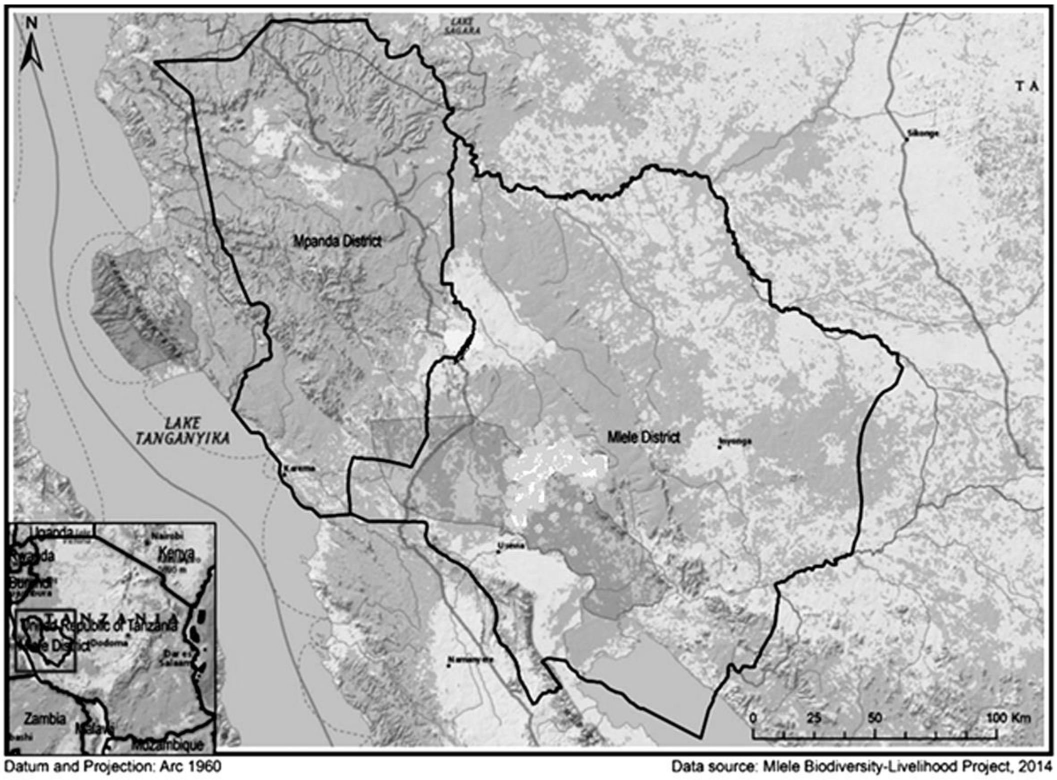

***Figure 1**: A map showing the location of the study area in Mlele District*

Data Collection

Questionnaire survey

Three villages were purposively selected from Inyonga Division, based on the criteria that they were practicing beekeeping and have reasonable number of beekeepers who practice both traditional and improved beekeeping in the study area. Villages selected were Nsenkwa, Ipwaga and Kanoge (Fig. 2). A set of structured questionnaire was used, within the selected three villages, 30% of the beekeepers were considered to be a good sample for the study. Thus, villages with more beekeepers had more respondents. At Nsenkwa village 41 respondents were interviewed (44% of 93 beekeepers), Ipwaga, 30 respondents (44.8% of 67 beekeepers), and Kanoge 30 respondents (52.6% of 56 beekeepers). A total of one hundred and one (101) respondents were interviewed.

Focus Group Discussion (FGD)

FGD was conducted to gather general information on status of beekeeping, its role in both livelihood improvement and conservation and major challenges facing beekeepers in Mlele. A total of 34 villagers that included beekeepers (both males and females), village leaders and some officials from the district council were invited and participated fully in the discussion.

Key Informants Interviews (KII)

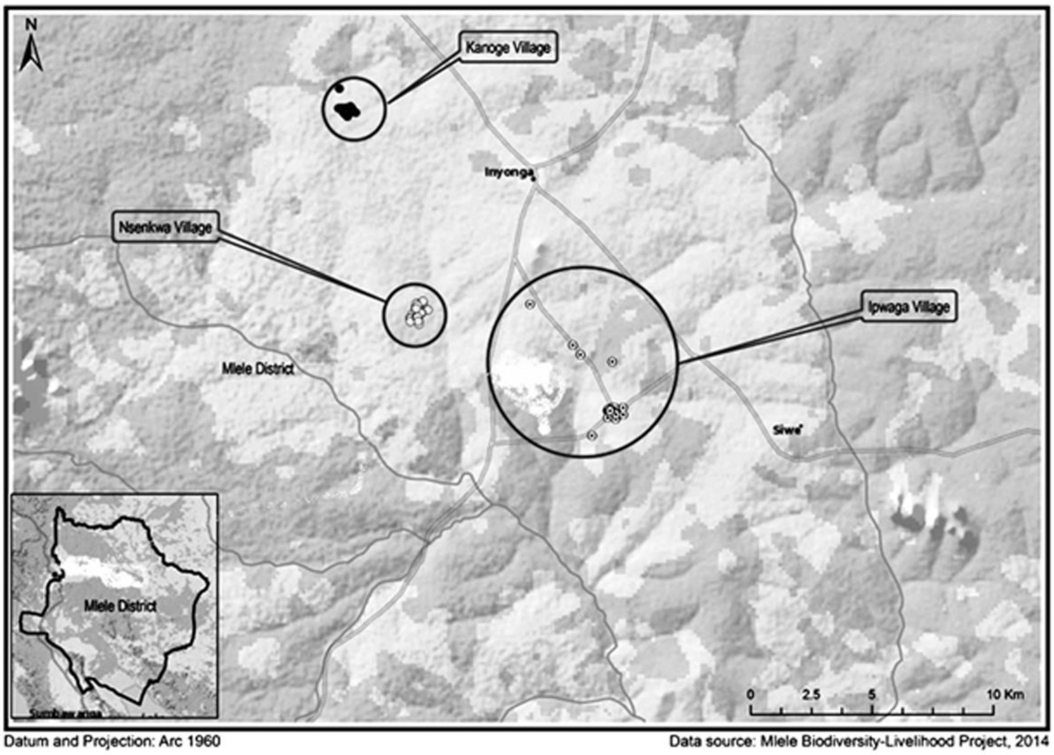

***Figure 2**: The map of study area showing the study villages*

During the survey, KII were conducted that incuded village leaders, district authorities, beekeeper group leaders, buyers and sellers of bee products, Association for Develpment of Protected Areas, Coordinator and Inyonga Beekeepers Association leaders. Information from the FGD and KII was used to support and validate data from the questionnaires.

Physical observations

Physical visit to some activities such as bee product processing, packaging, market place and a visit to the nearby bee apiary (Mlele Beekeeping Zone) was done.

Secondary data

Other relevant information was collected from literature search, and relevant institution offices such as District Natural Resources Office, NGO's, Inyonga Beekeeping Issociation and from the Ministry of Natural Resources and Tourism (MNRT).

Data Analysis

Data were analyzed using descriptive statistical tools such as frequency distribution and percentage to describe the socio demographic characteristics of beekeepers. Statistical Package for Social Science (SPSS, V. 20) was used for most of the data analysis. Results are presented in forms of tables, charts, frequencies and graphs. For quantitative data collected through questionnaire survey, analysis of variance was used for normal distributed data, otherwise non-parametric test was used. Content analysis was used to analyze data collected through FGD and KII.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of the respondents

Out of the total respondents' males constituted 92.1% of beekeepers in the study area (n=101, Table 1). Traditionally at Inyonga area, males dominate the beekeeping activity as a forest based practices, which are carried over from one generation to another. Making bark hives that are commonly used and sitting methods requires physical strength; involving tree climbing for hanging hives and during honey harvesting which favor men rather than women. It was also explained that, harvesting process requires long absences from home, which competes with women's family responsibilities. Similar reasons were reported in other African countries were traditional beekeeping is practiced (Van der Kleij and Simukoko, 2012). In Mlele it was reported that women play a significant role in food preparation (53%, n= 101) in the beekeeping camp for men while they are hanging hives, doing inspection and harvesting. Results also indicated that, the majority of respondents had access to formal education, 74% of respondents (n=101) had attended primary education, 25% secondary education, 1% tertiary education (vocation training) and 1% had non-formal education. Findings revealed that most of the respondents (35.6%, n=101) were within the age category of 36-45 years, which implies most of the beekeepers are in their active age of production. Among the beekeepers in the three villages, Konongo tribe constituted 45.5%, Fipa 27.7%, and the rest of tribe groups had less representation below 10% of respondents (Table 1). This signifies that the activity is still under the main dominant resident tribe of the area (Konongo).

Table 4: Socio-economic characteristics of respondents (n = 101)

	Frequency(n=101)	Percentage (%)
Gender		
Male	93	92.1
Female	8	7.9
Education		
Never been to school	1	1.0
Primary	75	74.3
Secondary	24	23.8
Tertiary	1	1.0
Age Category		
20-35	18	17.8
36-45	36	35.6
46-55	20	19.8
56-65	17	16.8
>65	10	9.9
Tribe		
Konongo	46	45.5
Fipa	28	27.7
Nyamwezi	8	7.9
Rungwa	4	4.0
Others (Hehe, Bungu, Rungwa, Pimbwe, Sandawe and Sukuma)	15	14.9

Types of beehives used in the area

Finding from this study revealed that, majority of beekeepers were using traditional hives and mainly bark and log hives. Results indicated that, 63% of the total recorded hives in the area (n= 11,928) were bark hives (Figure 3), beekeepers preferred them due to less costs (one bark hive was sold at TZS 3,000 to TZS 5,000; which is equivalent to US$ 1.9 to 3.1 respectively) and they are available in the area and sometimes can be easy constructed by family members. Unlike bark hives, improved hives (TTBH and TCH) were reported to have higher costs that ranged between TZS 60,000 (Equivalent to US$ 37.5) to TZS 120,000 (equivalent to US$ 75). At the same time skills and capacity on how to manage the improved hives was lacking among many beekeepers. This was mentioned as among the factors that had pushed back the majority of beekeepers to become less interested in changing from use of bark hives to improved hives. This result is supported by other researchers on hive preference by beekeepers in Ethiopia (Yemane and Taye, 2013; Mehari, 2007) who indicated that beekeepers avoided the use of improved hives mainly because of the cost of constructing and purchasing of modern hives and also due to lack of harvesting and processing equipment's to use improved hives. Similarly, Mehari (2007) in eastern Tigray in Ethiopia reported that modern beekeeping productions require high investment, specialized accessories, (further cost) and skilled personnel although yield better quality and quantity honey. Likewise, Ajao and Oladimeji (2013) in Kwara state, Nigeria, reported that beekeepers avoided modern hives as they are very costly and not within the reach of the beekeepers. This has resulted into low opportunities for beekeepers to adopt the use of improved beehives, which could make the business to become commercially viable enterprise.

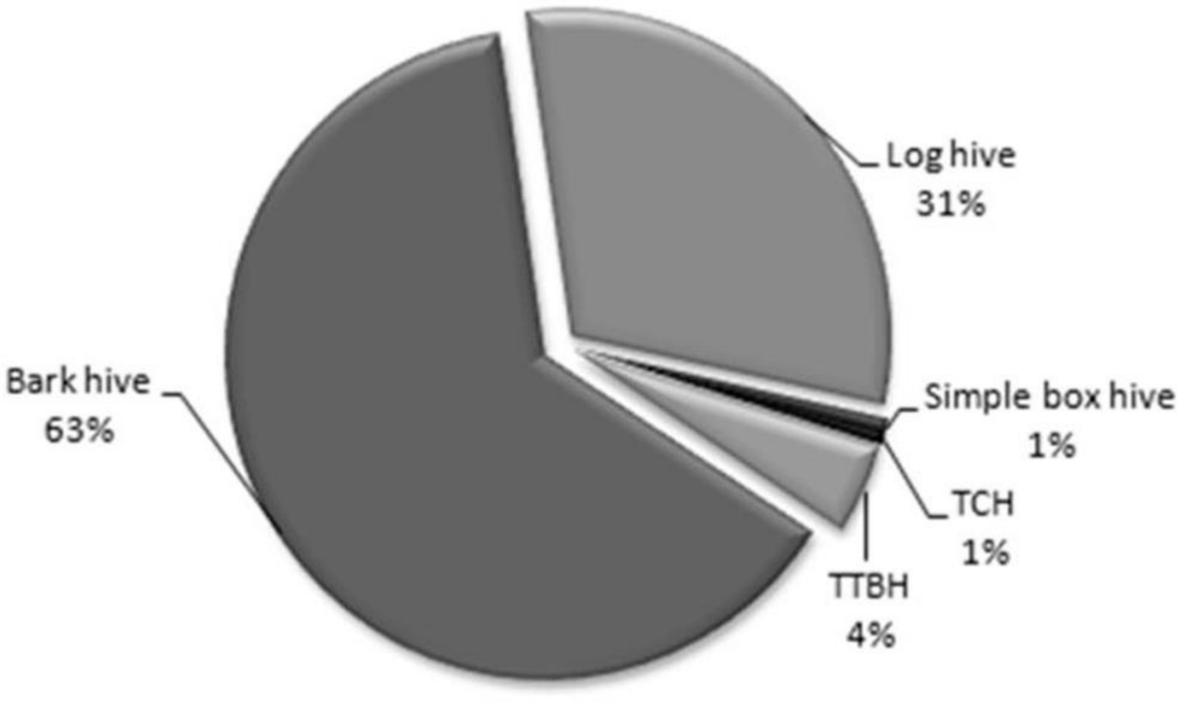

***Figure 3**: Proportional of respondents on the use of different hives (TCH=Tanzania Commercial Hive, TTBH=Tanzania Top Bar Hive)*

The honey production per hive was significantly different among the hives types (Kruskal Wallis Test; Chi-square =15.874, df=3, p<0.05). According to beekeepers who were interviewed, bark hive had higher production level per hive than log hive (Scheffe, P<0.05) in both seasons. In major season, average production for bark hive was 22 (±8) kg/ hive while log hive had 17(±8) kg/hive. The production of Tanzanian Top Bar hive (TTBH) and simple box hive (Box hive with neither flame nor bars) has fewer sample sizes for statistical comparisons. The average production of bark hives as reported by respondents was slightly higher than what was reported by Haesler (2012; cited in Weber 2013) who indicated an average of 20kg per bark hive per season. The higher production level in bark hives was explained by beekeepers being related to large sizes of the hives as compared to log hives, which were observed to have smaller volume. This has even considered encouraging beekeepers to continue using bark hives despite its ban since 2010 through the Tanzania Beekeeping Act no 15 of 2002 that, they are main causes of forest lossess due to the tree cuting and or debarking in the process of making bark hives.

Harvesting and processing of bee products.

Results indicated that, only two products honey and beeswax were harvested in the study area. Results indicated that harvesting and processing of bee products are done locally through traditional knowledge and skills. Fire setting during harvesting was reported by all beekeepers as the means to calm bees. Beekeepers reported to use this technique due to lack of appropriate protective gears. Most of harvesting was done during the night. The use of fire resulting into heavy smoke was reported to cause smoky odour in honey. The use of fire was also reported to cause death and absconding of bee colonies and destroy important bee fodders by causing frequent forest fires. It was noted that majority of beekeepers in the study area were using traditional method of honey proccessing, majority 57%, (n = 82) of those who responded to the question of how they process honey, reported to use traditional gravity method supported by a traditional strainer made up of tree barks (see plate 1, an axample of a traditional strainer). Hand smarshing and straining, boiling and straining were also reported to be among the common methods used in honey processing. It was also reported that honey decantation (squizing and melting through sun heat) using 200 litre drums was also common. The hygiene condition of these traditional equipment was reported to be questionable as some of these could result into contamination. Beeswax processing was done through boiling and straining using locally made special strainer for beeswax (Plate 2). Traditional processing equipment have been reported to be the major source of poor quality of bee products which has resulted into low income to majority of beekeepers as they are forced to sell their products at less price.

***Plate 1:**. Traditional honey strainer*

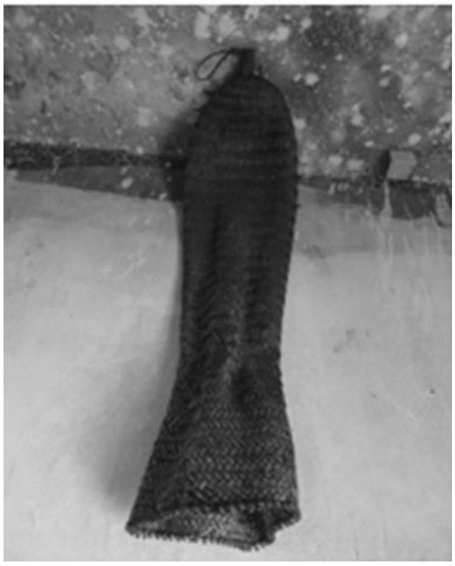

***Plate 2:**. Traditional beeswax strainer*

Table 2. Beekeeping constraints in the study are as reported from respondents

Constraint	No. Respondents	% respondents	Rank
Lack of bee equipment	48	20.4	1
Prolonged drought	33	14.0	2
Unreliable market and price fluctuation	21	8.9	3
Long distance to apiary (lack of transport)	21	8.9	3
Lack of capital	17	7.2	4
Lack of protective gears	16	6.8	5
Fire and forest destruction	16	6.8	5
Bee pests and predators	12	5.1	6
Delay of permit to enter game reserve	10	4.3	7
Lack of modern beekeeping skills	8	3.4	8

Low price of bee products	7	3.0	9
Modern hives are expensive	7	3.0	9
Climate change	3	1.3	10
Bee colon absconding	6	2.6	11
Inadequate beekeeping extension services	5	2.1	12
Few modern hives	3	1.3	13
Theft of bee hives	2	0.9	14

Main challenges of beekeeping practices in the study area

The study revealed that despite good initiatives to promote beekeeping in the area, there were several challenges that were noted and are considered to hinder beekeeping activities in the area. Among the major challenges includes use of bark hives out of 11,928 recorded in the study villages, bark hives constituted 63% which was considered to be a major threat to trees and mainly bee fodders. It was indicated that, among the most prefered species for making traditional hives (specifically bark hives), 55% (n=101) reported to use *Jurbenadia globiflora* species (common name; Muva) and *Pterocurpus angolensis* (common name Mninga) mainly for log hives. The two species were reported to be highly utilized. The high utilization of both *Jurbenadia globiflora* and *Pterocurpus angolensis* has a significant negative impact on bee plant conservation., that, species such as *Jurbenadia globiflora* forms part of the top most important bee fodder in the area due the plenty flowers it produces and its utilization by bee colonies. Bark hive making through this species thus threatens it existance. The high utilization of *Julbernadia* and *Brachystegia* species in Mlele was also reported by Hausser and Mpuya (2004) and that there were under threat.

Fire is the main tool used by all interviewed beekeepers to calm bees during harvesting. The use of fire was reported to cause death and regular absconding of bee colonies, loss of important bee fodders and biodiversity at large which results into less production and thus, less income. Other important challenges that were reported are indicated in table 2 bellow. Furthermore, apart from the analyzed constraints from beekeepers, other challenges reported by district officials and other stakeholders that need urgent solutions were, land conflicts between villages and Forest Management authorities, duplication of activities in similar villages by donors due to communication barriers, illegal tree cutting for timber and charcoal making also were reported as challenges in the area. Furthermore, cattle incursion into forest reserve, that causes major threat to beekeeping activities and poor record keeping at Inyonga Beekeeping Association and at village levels are also key threats.

Opportunities for beekeeping in the study area

Mlele District is among the higher beekeeping potential area in the miombo region. Despite some current challenges, there are some good opportunities for beekeeping. There are number of initiatives going on to promote beekeeping that include formulation of beekeeping groups and associations. Results indicated that 91.4% of respondents (n=101) belonged to beekeeping groups. A total of eleven (11) registered beekeeping groups (Table 3) and one Association (Inyonga Beekeepers Association, IBA) were recorded in the study area. Out of these groups, only two groups belong to women and are still new. From FGD, it was reported that, presence of beekeeping groups has brought together beekeepers for them to get easy access to extension services and support from both government and development partners. The existence of these groups is an indicator that awareness rising is going on in the district, however more efforts are needed to include more beekeepers in the groups as there are still many beekeepers who are operating at individual level.

Table 3. Beekeeping groups recorded in the study area

No.	Name of the group	Village	No. of members	Composition
1	Kilua Nsao	Nsenkwa	18	Men
2	Mzinga Nsawo	Nsenkwa	32	Men
3	Mama Nsenkwa	Nsenkwa	28	Women Group
4	Miombo	Nsenkwa	20	Men and Women
5.	Imala makoye	Kanoge	10	Men
6	Isanjandugu	Kanoge	*	Men
7	Kumilansao na Kutunga nsao	Kanoge	13	Men
8	Shoka ni mali	Kanoge	*	Men
9	Msitu ni Mali	Ipwaga	10	Men
10	Tutunze msitu	Ipwaga		Men
11	Mpingili	Ipwaga	*	Women group

Note: ** Records for total number of group members were not available*

It was also noted that, the government of Tanzania through the Ministry of Natural Resources and Tourism is currently advocating sustainable beekeeping through training in appropriate beekeeping. A number of appropriate beehives (TTBH and TCH) have been donated to various beekeeping groups in Mlele. There is also ongoing sustainable beekeeping awareness raising and training opportunities from ADAP and other key stakeholders.

Other opportunities that were noted in the area include the increased high market demand for honey for both domestic consumption and export by different customers and organizations, and the area is rich in bee forages all year around. Also, the availability of skilled beekeepers having long experience of indigenous knowledge and skills that are motivated to adopt appropriate technologies and undertake beekeeping intensively are among the opportunities to enhance beekeeping in the area. It was also noted that, there is a conservation initiatives for forest reserves. Mlele District authority has provided a support to beekeepers by engaging them in Participatory Forest Management which resulted into establishment of Mlele Beekeeping Zone (850km^2), main actors are Mlele District Council, Tanzania Forest Service, Inyonga Beekeepers Association and Association for Development of Protected Areas. Beekeepers have access to protected forest and reserved areas where they practise beekeeping through special permits and district and protected areas authorities support them. This has encouraged beekeepers, and thus they are responsible for the protection and conservation of the forest reserve.

CONCLUSION

Generally beekeeping in the study area is traditionally based activity dominated by men. The use of traditional methods in both production and processing (especially use of bark and fire) were considered to be the major threat and a cause of biodiversity loss in the area which resulted into low quality of bee products hence less income to beekeepers. Furthermore, the continuation of traditional beekeeping methods specifically use of bark hives and fire during the processing process are threatening biodiversity of the area. Among the identified important bee fodder, *Jurbenadia globiflora* (Muva) species was noted to be widely used for making bark hives and other related traditional beekeeping equipment this in turn posses threat to its existence.

It was also noted that, many beekeepers are aware of the opportunities for beekeeping in the area, and on the importance of biodiversity conservation as a means for sustainable beekeeping. Results also revealed that despite some damages caused by inappropriate beekeeping activities, beekeepers in the area have started to practice appropriate beekeeping techniques for sustainable conservation of biodiversity. Other beekeeping opportunities includes market demand of bee products, government and development partners support on beekeeping activities and establishment of Mlele Beekeeping Zone.

RECOMMENDATIONS

With the current challenges, the study reccomends the following:-

- Provide adequate training to beekeepers in the study area on apropriate beekeeping practices, that will increase not only the profitability of the bee enterprise but also for improving biodiversity conservation in the area.
- Strenghtern the existsing and establishment of beekeepers association and beekeeping groups that will help in annexing financial aids, marketing information and inputs from government and non-government organizations
- Strengthen the joint collaboration between stakeholders working on beekeeping industry in the area and create market channel that will take care of price fluctuartion problems.
- Encourage investor to invest in processing and selling of beekeeping equipment within the district to help beekeepers to easy access the appropriate beekeeping equipment at reasonable prices.
- Facilitate and promote a special campaign to protect tree species that are considered to be the most important bee fodder, special attention to be given to *Jurbenadia globiflora* (Muva) *and Pterocarpus angolensis* (Mninga) which are highly utilized.
- Long term research should be conducted to determine further the adoption of appropriate beekeeping techniques among beekeepers in the area, the level of biodiversity conservation in the bee apiaries and hive type profitability.

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BUTTERFLY SPECIES AND THEIR RELEVANCE TO CONSERVATION IN WILDLIFE MANAGEMENT AREAS, SOUTHERN TANZANIA

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ABSTRACT

The objectives of this study were to assess butterfly communities, and to determine the influence of disturbance on individual butterflies, species richness and composition within five Wildlife Management Areas (Mbarang'andu, Kimbanda, Kisungule in Namtumbo District; Nalika and Chingoli in Tunduru Didistict) located in Ruvuma landscape. The survey was conducted between September and November 2014 using sweep nets and visual observations. A total of 545 butterflies from 90 species that belong to 6 families, were recorded. Kruskal-Wallis test revealed no significant difference in number of individual butterflies across the WMAs. Among the five WMAs studied, butterfly species richness was highest in Mbarang'andu (28.7 ± 0.81) and lowest in Kimbanda (2.2 ± 0.29). Mean number of individual butterfly was slightly higher (3.1 ± 0.26) in the miombo woodlands compared to the riverine forest (2.9 ± 0.37). Even though there is some degree of environmental destruction caused by communal settlements in the WMAs, there is a correspondingly high diversity of plants to support identified butterfly species. However, further destruction of vegetation could affect species richness and abundance of butterflies within the study area. Hence, we recommend that more resources and effort such as human resource and funds be in place to safe guard these WMAs from any environmental degradation for the benefit of present and future generation.

Keywords: Butterfly, conservation, disturbance, Ruvuma, WMAs

INTRODUCTION

The concept of community involvement in wildlife management has been actualized through formation of Wildlife Management Areas (WMAs) (Songorwa, 1999; Walsh, 2000). WMA approach represents Government of Tanzania's interpretation of community wildlife management and as a formal recognition of the link between conservation, economic growth, and poverty reduction (WWF, 2014). The concept is aimed to empower local communities to access direct benefits, make informed management decisions and to develop an enabling institutional arrangement for investment in wildlife-based land uses and conservation of the resource (Kellert et al., 2000). It is presumed that, by restoring traditional rights over access to resources critical to their livelihoods, local people will be motivated to align their behaviors with conservation goals. Essentially, the focus is to change rural people's perceptions, behaviors and practices and shape the same towards achieving conservation goals (Songorwa, 1999).

Encroachment to protected areas contributes to the decline and extinction of wildlife worldwide (Songorwa, 1999; Hilborn et al., 2006). Human population increase has been explained as the main cause to encroachment into protected areas and a major factor contributing to the global depletion of natural resources and rise in demand of land for settlement, economic related activities, agriculture and fuel to improve their livelihoods (Lotze et al., 2006). The overall outcome of such problems is the loss or local extinction of some fauna species including butterfly communities.

Butterfly communities (Lepidoptera) play significant ecological roles in different habitats including forests, natural savanna and agricultural landscapes. Their larval stages are particularly important food sources for breeding birds as well as the adult butterflies which provide food for birds.They also play part in the recycling of nutrients and they provide important ecological services for native wild plant species and crops in many ecosystems of the world (Davis et al., 2008) and are of great importance in conservation monitoring. Some of species are particularly sensitive to environmental degradation and changes in habitat structure. Human disturbances like cutting of trees, cultivation and overgrazing by cattle in low or high elevation can also influence butterfly distribution (Hodkinson, 2005). For example, it has been shown that some tropical butterflies show changes in species composition in response to selective logging (Hamer et al., 2003), which would likely affect ungulates or carnivores or even other wildlife species in the food cycle.

Protection and conservation of Lepidoptera diversity in the study area require extensive understanding of their foraging behaviors and distribution. In East Africa, little attention has been given to smaller animal taxa such as the butterfly especially in both reserved and non-reserved areas. In Tanzania, a few studies of tropical savanna have been conducted to investigate butterfly species diversity in the fate of habitat disturbance. For example, Fitzherbert et al. (2006), examined diversity in ephemeral habitats at Lake Katavi in Tanzania; Bonnington (2010) investigated how elephants (*Loxodonta africana*) disturbance affects butterfly assemblages of miombo habitat in the Kilombero Valley, southern Tanzania. Nevertheless, in spite of their significance as indicators of disturbance in natural ecosystems, little attention has been directed to examine the influence of anthropogenic disturbances on numbers of individual and richness of butterfly communities in the Ruvuma landscape. The patches of the wetland in all the five WMAs (Mbarang'andu, Kimbanda, Kisungule, Namtumbo, Nalika and Chingoli) are threatened by increasing human activities such as rice cultivation, cattle grazing, deforestation, mining, increased poaching and high incidences of bush fires (Borghesio et al., 2009). The overall objective of this study was to assess the status of butterfly communities on the influence of disturbance on number of individual butterflies, species richness and composition as an important indicator of environmental degradation in the Ruvuma landscape. Specifically this objective will be achieved under two key questions:(i) do the numbers of individual butterflies, richness and composition differ among the five WMAs in Ruvuma landscape and the main vegetation types?; and (ii) are the numbers of individual butterflies, species richness and composition in the study area influenced by human disturbance (burning, grazing and cultivation)? The information obtained from this study will help to understand the composition of butterflies' communities and their role for conservation of the Ruvuma landscape in general and the five WMAs.

METHODS

Study area

This study was conducted in the Ruvuma landscape. The Ruvuma landscape is an extensive trans-frontier area of approximately 278,950 km^2, flanking the Ruvuma River (Mnrt, 2006), spanning Tanzania's southern regions (Coast, Lindi, Mtwara, Morogoro and Ruvuma), to Mozambique's northern provinces of Niassa and Cabo Delgado, forming the largest wilderness area of unfragmented miombo woodland, coastal forests and associated ecosystems remaining in Africa. The study area comprised 10 villages located between latitude 9° 52' 8" to 11° 45' 36" South and longitude 35° 41' 42 to 37° 19' 43" East (Figure 1).

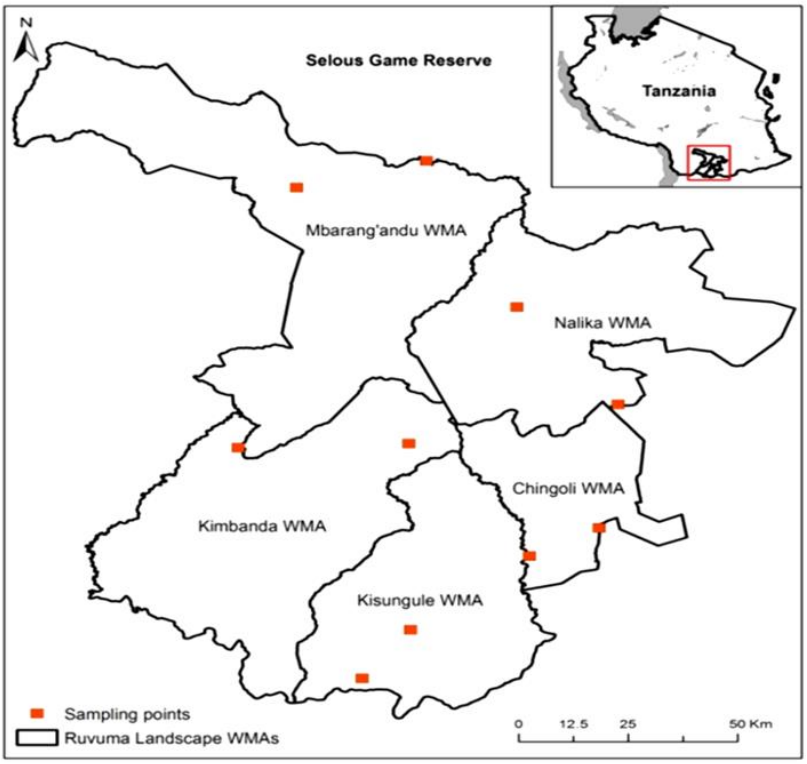

Figure 15: *Map of Ruvuma landscape showing the five WMAs and the location of sampling sites*

The Ruvuma landscape borders with Selous Game Reserve in the north and the Niassa Game Reserve (Mozambique) to the south. The landscape forms the largest unfragmented miombo woodlands, dominated by *Brachystegia* spp, *Julbernardia* spp. and *Isoberlinia* spp, *Afzelia quanzensis*, *Pterocarpus angolensis*, and the rare and threatened species of plant such as *Dalbergia melanoxylon*. Other vegetation types include wooded grasslands, open savannahs, granite inselbergs, seasonal and permanent wetlands and riverine forests along numerous perennial and seasonal streams (Baldus & Hahn, 2009). The area is dominated by small hills, whereas the southern part towards the greater Ruvuma River is dominated by slightly undulated to flat isolated hills (Baldus & Hahn, 2009). The rainfall pattern is unimodal spanning from late November to April and May with a mean annual rainfall of 800-1200 mm in a north-south gradient, and the mean annual temperature is about 21°C following the Köppen system (Köppen, 1931).

Sampling design

A total of 10 separate sites covering an area of approximately 40,000 m^2 were established in the five WMAs, one site in each vegetation type i.e. miombo woodland and riverine forest. A minimum of two sites were sampled in each WMA due to budget constraint. All disturbances such as level of grazing by livestock, wild fires burning, cultivation and cutting down of trees were recorded and categorized into three scales as low, medium and high;, whereas the low level meant presence of just traces of disturbance, medium as half of the sampled area was disturbed, and high meant the whole sampled plot was either burned, grazed or farmed or both. Each site was sampled for three consecutive days from 20th September to 25th November 2014 during the dry season. Decision on the number of sampling days was based on a pilot study that was done for six days prior to the commencement of data collection, which was from 14th of Sept to 19th of Sept 2014.

Each site was sampled using two complementary methods. First, butterflies were collected using a hand-held butterfly net (35 cm in diameter). Random searches in an area of approximately 40,000 m^2 were conducted by four to five observers for a minimum of 2 hours, for each trap day from 09:00 hrs to 11:30 hrs, and from 15:00 hrs to 17.00 hrs. This method was used to sample butterflies in the miombo, forest under-story/scrub/thicket and around ground herbs and grasses. Timed sweep netting was conducted within each vegetation plot. Data on the species name, types of disturbance and associated vegetation types were recorded on standardized data sheets. Unidentified individuals were kept in special envelopes and later identified to species level by the aid of field guide book by Kielland (1990) as well as Larsen (1996).

Second, transect method as explained by Pollard (1977), Thomas (1983), Munyuli (2012) and Sinclair et al. (2015) was used to sample butterflies, that is visual observation of flying butterflies along the transect were recorded. This method was used to record butterfly species that are common and easy to identify to avoid over collection. Sampling time (both by visual observation and catching by sweepnets) started from the morning (09:00 hrs to 10:30 hrs) once it was warm enough for butterflies to fly, then in the noon (12.00 hrs to 14.00 hrs) and again in the evening (15:00 hrs to 17:00 hrs).

Statistical analysis

The butterflies' data were tested for normality using the Shapiro-Wilk (W) Test and the Kolmogorov-Smirnov (KS) test. The data were found not to be normally distributed even after data transformation. Therefore a non-parametric Kruskal-Wallis (KW) test was used to examine differences in multiple independent samples among WMAs (Crawley, 2013). Butterfly species in the same habitat in different localities of WMA's were compared using Kruskal-Wallis KW-test to see the effect of human activites in the Ruvuma landscape. The above test was done in order to indicate which habitat has more disturbance than the other through defforestation, grazing by cattle and clearing for agriculture reducing habitat heterogeinity. For example, riverine forest in Nalika WMA site was compared with riverine forest in Kimbanda WMA vs riverine forest (Kisungule WMA) vs forest (Chingoli WMA) vs forest (Mbarang'andu WMA).The same comparison was done for the miombo woodland in the entire Ruvuma landscape. Species richness estimates were obtained following Shannon & Weaver (1949). This index uses two biodiversity indices including, richness and number of individuals to determine which WMA had the greatest biodiversity for the butterfly community. Butterfly species richness is described as the number of different species in each area, while butterfly abundance is represented by the number of individuals counted in an area per unit time. Generalized mixed effects model with Poisson errors was used to observe differences between disturbed and undisturbed habitats by applying the lmer function in R (Crawley, 2013). We fitted cultivation and grazing as treatments (fixed effects) and treated other factors (a particular elevation point within habitat, within a site or village) as random effects defined by the spatial structure.

RESULTS

Overall, 545 butterfly individuals belonging to 6 families, 41 genera and 90 species were recorded in the study area. Species richness of four families (nymphalidae, hesperiidae, lycaenidae and pieridae) was higher in Mbarang'andu while species richness recorded in Kimbanda was low which did not exceed 10 species (Figure 2A). Two families, acraeidae (recorded only in Kimbanda and Mbarang'andu) and papilionidae (only in Kimbanda and Chingoli) had the least proportion of papilionidae (0.56%) and were both recorded only in the riverine forest (Figure 2B). Kruskal-Wallis test revealed no significant difference in number of butterfly individuals across the five WMAs (χ^2 = 9.9214, df = 4, P = 0.4181 (Figure 3).

Except for Kisungule WMA where numbers of butterfly individuals were higher in riverine forest, butterfly numbers were always higher in miombo woodland habitats than in riverine forest for the rest of the WMAs (Figure 4).

The number of individual butterflies was slightly higher (3.1±0.26) in the miombo woodland compared to the riverine forest (2.9±0.37) but was not statistically different (W = 3988, P = 0.678). The mean (Mean ±SE) of butterfly richness in the miombo woodland (23±0.91) was significantly higher (W = 5550, P < 0.0001) than in the riverine vegetation (mean = 14.4±0.39). A comparative analysis indicated that 49% of species were recorded in the miombo woodland, 31% in riverine forest and 20% were found in both vegetation types.

Results from mixed effect model analysis indicated that sites with low (P = 0.0092) or medium (P = 0.035) grazing levels by cattle produced significantly low number of butterfly individuals than sites with no grazing. Butterfly numbers were not influenced by cultivation differences.

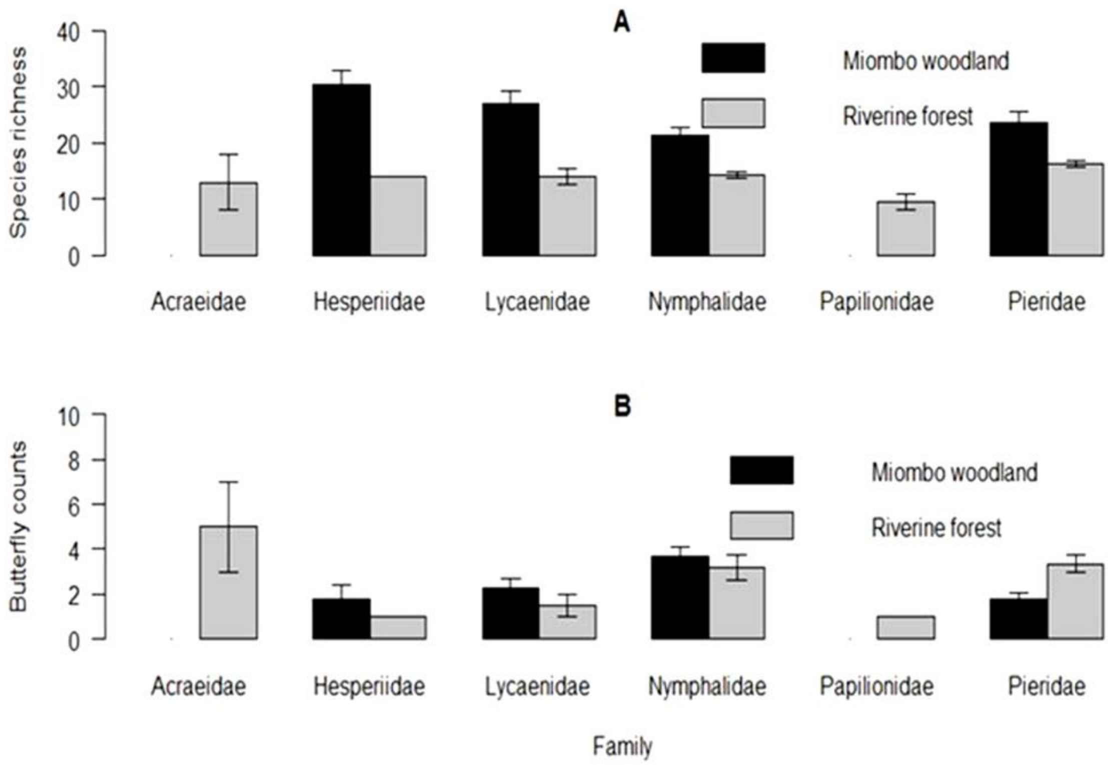

***Figure 2**: Accumulated number (mean±SE) of butterfly species grouped in six families (A) and distribution of individual butterflies' counts (mean±SE) in different families (B) recorded between miombo woodland and riverine forest in WMAs of the Ruvuma landscape.*

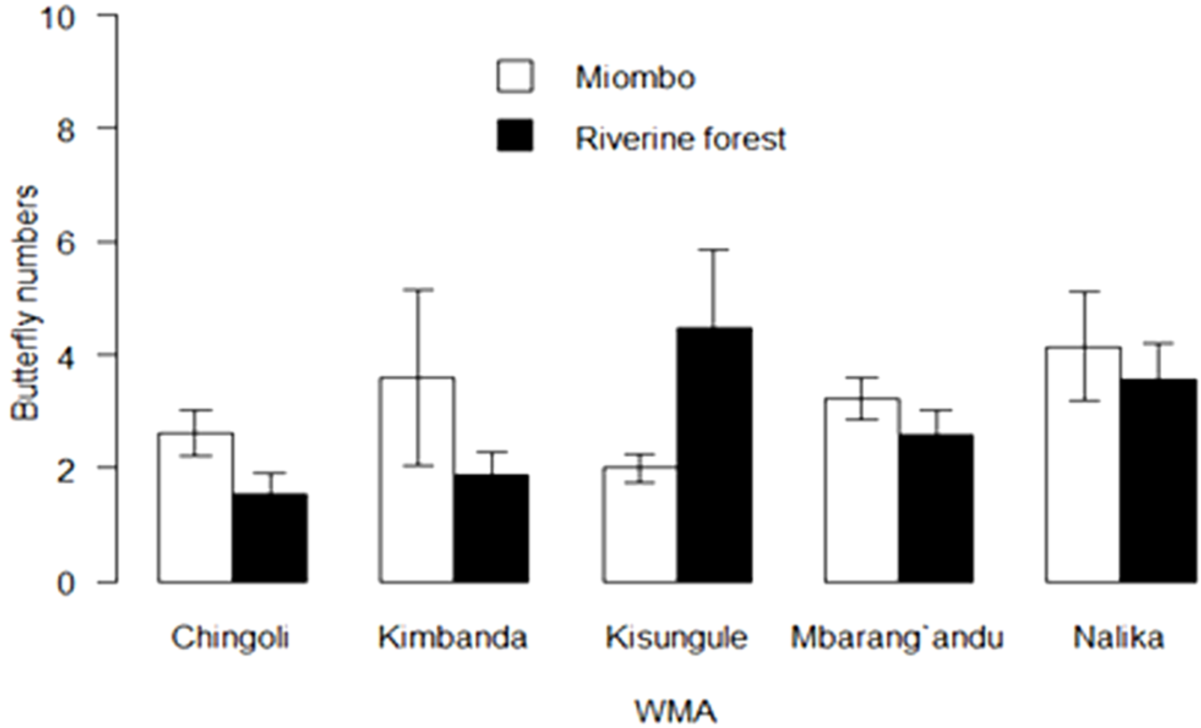

***Figure 3**: Numbers (mean±SE) of individual butterflies variation across vegetation types in the Ruvuma WMAs*

Among the random effects sites and habitat type did not influence butterfly numbers while very modest differences in butterfly numbers was due to differences in elevation (Mean = 696.6 m, Variance = 0.01).

When we fitted cultivation and grazing as random effects instead of fixed effects along with other random effects site, elevation and habitat type, our model slightly changed, the variance attribute for elevation became zero while the variance attribute for grazing increased (Mean = 0.65, Variance = 0.83) indicating that much the biggest cause of variation in butterfly numbers was differences in grazing intensity between sites. Differences between each of the other random variables elevation, cultivation, site and habitat showed no significant influence on butterfly numbers (Mean = 3, variance = 0).

DISCUSSION

The overall results suggest that butterfly abundance and richness was significantly influenced by human disturbance, in line with findings of Fitzherbert et al. (2006) who reported lower butterfly abundance and species richness in disturbed habitats than in habitats that had little human alteration in the Katavi ecosystem. Of the five WMAs, the Mbarang'andu

WMA , showed the lowest level of human disturbance, and this was the least affected by grazing, a possible reason for the highest richness in butterfly species in this WMA. Although butterfly numbers in Kimbanda were nearly the same as for other WMAs, butterfly richness was the lowest, possibly due to the fact that our observation focused on intensive rice cultivation, thus land clearance for rice farms was in the highest peak compared to the other WMAs. This finding suggest that a cleared land for cultivation caused some species to disappear from the area but at the same time attracted an influx of certain butterfly species which are attracted by disturbance levels e.g. see also in Akite (2008) and Sinclair et al. (2015). This is the reason why the overall effect of cultivation was not significant in the current study.

Overall, we did not encounter variations in butterfly numbers between miombo and forest vegetation types but we observed significant differences in butterfly species richness. This is an indication that certain species out of the total observed were habitat specific because they were able to obtain their preferred resources only from the miombo or forest areas, this was also clearly described by Warren et al. (2001), who showed direct association between butterfly diversity and habitat type or conditions with changes. According to Warren et al. (2001), habitat modification would influence diversity of specialist butterfly species. In the current study, in line with this, relative to the other WMAs the miombo woodlands in Kisungule and Chingoli WMAs faced relatively higher levels of both cultivation and grazing, which would possibly explain the observed lower numbers of butterfly in these areas.

Butterfly species like *Acraea neobule, Junonia sophia, Bicyclus safitza* (Nymphalidae) and *Catopsilia florella* (Pieridae) appeared to be well adapted in highly disturbed landscape and were been recorded throughout in all WMAs in the Ruvuma landscape. These results are similar to observations reported in Central Uganda by Munyuli (2012). They are probably typical farmland species as no reports have ever mentioned them among the dominant species of forest ecosystems in Tanzania. The presence of above butterfly species indicates that the WMAs in Ruvuma landscape are still highly disturbed by human activities and thus more efforts should be employed to curb the situation.

An important butterfly species *Pentila rondo* (Lycaenidae), an endemic to Tanzania in South-eastern part of the country to the Rondo Plateau and the area West of Lindi (Kielland, 1990) was found in a small pocket of riverine forest surrounding the water source at Kimbanda WMA. Another forest dependent species *Protogoniomorpha perhassus* (Nymphalidae) was also recorded at Mbulukasese riverine forest in Mbarang'andu WMA. This indicates the importance of the riverine forest for butterflies and the vulnerability of forest dependent species. *Neocoenyra petersi* (Nymphalidae) a species endemic to Tanzania was also recorded in the Ruvuma landscape at the riverine grasses, as well as at Mbulukasese riverine forest in Mbarang'andu WMA. The endemic species found in these WMAs indicate how important these WMAs are for conservation of wildlife species.

The insignificant variation in number of butterfly individuals across the five WMAs was perhaps due to habitat similarity among them and almost similar effort of protection. The finding in Selous Game Reserve showed that, the habitat heterogeneity has a positive great impact on insect diversity including butterflies (Ngongolo, 2013).The higher number of butterfly individuals in the Nalika WMA can be explained by the high number of plant species which lead to habitat heterogeneity which provides host plants for breeding and foraging. Study by Ngongolo & Nyundo (2013) conducted in Selous Game Reserve observed that, number of insect individuals increased by the habitat heterogeneity which can be caused by variation of plant species.

The highest species richness of butterflies was found to be associated with miombo woodlands (e.g. see also in Kielland, 1990; Larsen, 1996). Factors governing higher butterfly community structure and composition in miombo woodland are not fully known and needs further investigation; the results from such study may give insight into how miombo woodland play a significant role in the distribution and richness of butterfly species in Ruvuma landscape. A possible explanation is that butterflies visit miombo woodlands for possibly supplemental nectar resources not found in the adjacent small patches of forested areas outside the miombo woodland. However, the extensive removal of forest cover due to anthropogenic activities like bush burning and agriculture may be responsible for the low record of forest dependent species (31%) only 51 butterfly individuals being recorded. Unfortunately, much of the forest has been converted to farmland, so drastically reducing the habitat for butterflies.

The low number of butterfly individuals observed in grazed area of the five WMAs in Ruvuma landscape was due to removal of plant parts such as flowers which provides a continuous supply of nectar resources and habitat in which females can oviposit and/or the larvae can feed or complete their development cycle (Rausher, 1979). However pointed out that overgrazing produces inappropriate conditions for butterflies, which resulted into butterfly populations collapse, the same finding were reported by Bowman et al. (1990); Hamer & Hill (2000) and Hamer et al. (1997).

CONCLUSION AND RECOMMENDATIONS

Butterfly species richness in miombo woodlands of southern Tanzania in the five WMAs was much higher than expected. This indicates that butterflies could be visiting miombo woodlands for possibly supplemental nectar resources not found in the adjacent small patches of forested areas outside of the miombo woodlands. Finding from this study indicates that the five WMAs are under great threat due to anthropogenic activities. While recently there has been a widespread operation to convert riverine flooded forest for the cultivation of rice in turn affecting the forest-dependent butterfly species, land conversion of flooded grassland and miombo woodlands will induce a marked loss in butterfly richness in areas lacking protection within the next decade. In this case, it is suggested that the adjacent community be involved in conservation of biodiversity in the WMAs. Land use planning should be encouraged and implemented among local communities in order to put aside land for biodiversity conservation. The feasibility study on butterfly farming in the area should be carried to assess its possibility and eventually the community participates in the butterfly farming, the activity that will increase the house hold income and improve the relationship between local community and the conservation authority and win their support in conservation of the biodiversity in the WMAs.

There is a need for giving conservation education to the local communities on the importance of conserving biodiversity resource, since WMAs can be used for study and training for students in terms of attachments, internships and research projects if are properly conserved. Also, WMAs can be potential tourist attractions and activities include bird watching, butterfly viewing, and landscape hiking as well as photographic. If the tourism will be developed it will create employments and increase income around the Ruvuma landscape.

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APPENDIX

THE 10TH TAWIRI SCIENTIFIC CONFERENCE;
SUMMARY OF PAPERS PRESENTED

THEME: The future of Wildlife Conservation in the face of Increasing Anthropogenic Demands

Key Note speakers/papers		
No.	**Paper**	**Presenter/Author**
1	Long-term field experiments: what do we learn and when do we learn it?	Mick Crawley
2	Sustaining wildlife conservation in growing socio-economic demands: can the African elephant survive the current wave of poaching?	Alexander Sorongwa
3	Livestock-Wildlife-Human Interactions: Challenges for control of zoonoses and emerging infectious disease	Julius Keyyu
SUB-THEME: WILDLIFE ECOLOGY AND ECOLOGICAL INTERACTIONS		
4	Wildlife monitoring: are ground surveys necessary?	Tim Caro
5	Challenging co-existence; lion habitat use and movement patterns in Ngorongoro's multiple-use landscape.	Ingela Jansson *et al.*
6	Movement pattern and home range sizes of the reintroduced wild dog packs in the Serengeti National Park, revealed by the GPS satellite collars.	Eblate E. Mjingo *et al.*
7	Inventory of the Tanzanian Orthoptera fauna and scientific applications	Claudia Hemp
8	Using remote sensing to investigate patterns and drivers of vegetation change in the Serengeti ecosystem from 1984 to 2011	Anna B. Estes, *et al.*
9	Body size and age in elephants of Mikumi National Park: Jaw measures indicate smaller size	Fredrick Mofulu, *et al.*
10	Recruitment and survivorship of the Kihansi Spray Toad (*Nectophrynoides asperginis*) in captivity	Nahonyo, C. L. and Goboro, M. E.
11	Vulture monitoring program in Southern Tanzania	Corinne Kendall, *et al.*
12	Butterfly species and their relevance to conservation in Wildlife Management Areas of Ruvuma Landscape, southern Tanzania	Ally Nkwabi *et al.*

Key Note speakers/papers		
13	Understanding the drivers of wildebeest movement	Elaine Ferguson
14	Studying collective animal behavior from aerial and space-based platforms.	Mutayoba, B and Lacey Hughey
15	Investigating the 'smaller majority' of the Udzungwa Mountains for larger questions and wider applications	Jagoba Malumbres Olarte
16	Dash and Dine: quantifying individual variability in prey handling times in wild cheetahs	Anne Hilborn, *et al.*
17	Activity Patterns of Black-and-White Colobus Monkey *(Colobus guereza caudatus)* in Rau Forest Reserve, Tanzania	Abraham Eustace, *et al.*
18	Spatial distribution of mitochondrial lineages of Tanzanian baboons	Zinner, D. *et al.*
19	Butterflies of Kihansi Gorge Forest in Tanzania	Devolent Mtui, *et al.*
20	Masai giraffe demography in the Fragmented Tarangire Ecosystem"	Derek E. Lee, *et al.*
21	Dramatic Population Decline of Ashy Red Colobus Monkeys (*Piliocolobus tephrosceles)* in Mbuzi Forest, Rukwa Region, Tanzania	Mohamed Kibaja
22	Sex-specific survival of juveniles of black coucal and white-browed coucalinthe Usangu plains of Southwestern Tanzania: preliminary findings	Ignas Safari and Wolfgang Goymann
23	A Holistic Indicator Selection Protocol for Identifying Measures of Conservation Success Using Conceptual Models	Andrew R. Marshall and Fadhili M. Njilima,
24	Vultures – a conservation challenge for Africa	P. Kariuki Ndang'ang'a and Julius Arinaitwe
25	Insights into long-distance dispersal by African wild dogs (*Lycaon pictus*) in East Africa	Emmanuel H. Masenga, *et al*
26	Assessment of diets taken by frogs around Mazimbu Campus, Morogoro	Ndibalema V.G. and Elisante, A
27	Effect of Land Cover–Land use Change on Abundance of Large Herbivores in the National Parks in Tanzania	Devolent Mtui and Christopher Lepczyk
28	Using Camera Traps to Infer the Numbers and Habits of Crop-raiding Elephants in Udzungwa Mountains National Park, Tanzania	Josephine Smit, *et al.*
29	The Udzungwa Red Colobus (*Procolobus badius gordonorum*) in highly modifies habitat of Kalunga rubber plantation Morogoro Tanzania	Samuel Mtoka *et al.*
30	Diet composition of golden jackal, *Canis aureus* in	Temu, S. *et al.*

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	the Ngorongoro Crater, Ngorongoro Conservation Area, Tanzania	
SUB-THEME: HUMAN WILDLIFE INTERACTIONS		
31	Scaling up of chili based techniques and validation of phantom drones for mitigation of crop raiding elephants in Tanzania (MICRET)	David Olson, *et al.*
32	Impacts of Tanzania's Wildlife Management Areas	J. Bluwstein, *et al.*
33	Human wildlife interaction: Impacts to conservation and livelihood at Saadan National Park	Monica Shilereyo
34	The Last Linkage: a forgotten Wildlife Management Area and the final connection between northern and southern Tanzania	Jasson Riggio and Tim Caro
35	Man-eating behavior manifestation and consequences for lion, leopard and hyena conservation in Tanzania	Ikanda, D., and Kissui, B.
36	The human dimension of blockage of wildlife corridors in the Tarangire-Manyara ecosystem	James V Wakibara and Gladys Ngumbi
37	Effects of Poaching on Elephant Demography, Behaviour and Tusklessness in Ruaha-Rungwa	Trevor Jones *et al.*
38	Assessment of livestock loss due to spotted hyena (*Crocuta crocuta*) in selected villages of Rorya District, Tanzania	Mrimi D. *et al.*
39	Knowledge and attitudes of communities on small mammalian carnivores in MBOMIPA wildlife management area, Iringa, Tanzania	Alphonce M. Msigwa, *et al.*
40	Enhancing Tourist Opportunities to View Spotted-Necked Otters (*Lutra maculicollis*) at Rubondo Island National Park: Can the apriori Location of Latrines Simplify Identifying Best Viewing Areas	Bridget Amulike, *et al.*
41	Tanzania and the natural world heritage designation: Does it matter?	James V. Wakibara and Beatrice M. Kessy
42	Reversing the trend of Wildlife crime in Tanzania: Challenges and Opportunities	Jafari R. Kideghesho
43	The impact of over-speeding on vertebrates' road kill in the Serengeti ecosystem, Tanzania	Richard D. Lyamuya, *et al.*
44	Local people knowledge and perception towards African wild dogs (*Lycaon pictus*) release in the Western part of the Serengeti ecosystem, Tanzania	Emmanuel H. Masenga, *et al.*
45	Use of ostrich (*Struthio camelus*) products: exploring the potential of improving rural livelihood	Flora Magige and Eivin Røskaft

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46	Spotted-necked Otters and Rubondo Island National Park, Tanzania: The Process of Developing an Ecotourism Flagship	Tom Serfass and Sadie Stevens
47	Predicting factors contributing to crop raids by elephants in Amboseli ecosystem, Kenya	Kenneth Kimitei, et al.
48	The effect of quarry mining on the diversity of invertebrates in peri-urban Dar es Salaam.	Upendo Richard
49	Influence of Human-induced Habitat on Avifauna Diversity and Abundance around Lake Jipe Wetlands	Christina Daniel Kibwe and Alex W. Kisingo
50	Examination of Typologies of Human – Wildlife Interaction in the Grassroots' Governance of Wildlife Resources in Tanzania	Montanus C.Milanzi
51	Poaching mortality, trophy harvest mortality and spatial displacement and the decline in Elephant Loxidonta Africana population of the eastern Selous Game Reserve, Tanzania.	Ikanda, D.K. et al.
52	Status and economic value of livestock-wildlife conflict in West Kilimanjaro, Tanzania	Joyce E. Kombe, et al.
53	Illegal activities contribute to significant biodiversity decline in protected areas across the globe: a review	Alfan A. Rija, et al.
SUB-THEME: CLIMATE CHANGE		
54	Does seasonal variation affect tropical forest mammals' occupancy and detectability by camera traps? Case study from the Udzungwa Mountains, Tanzania	Emanuel H. Martin, et al.
55	Modeling Past, Present and Future Ecosystem, Climate and Human Interactions in East Africa Savannahs	Rebecca Kariuki, et al.
56	Kilimanjaro under Global Change	Andreas Hemp
57	Impact of climate change and land use on local butterfly pollinators: A Case of Dar es Salaam City, Tanzania	Adelaide Sallema
SUB-THEME: WATER RESOURCES AND WETLAND CONSERVATION		
58	The water catchment values of Loliondo Game Controlled Area: Implications for the conservation of Serengeti National Park	James Wakibara, *et al.*
59	Can Water Resources Lead to Pro-Poor Growth?: A Comparative Study on Lake Victoria and Lake Tanganyika Fisheries in Tanzania	Odass Bilame and Janemary Ntalwila
60	Assessment of Surface Water Quality along the Loliondo Game Controlled area segment of the	Kaswamila, A. L., *et al*.

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	Proposed Highway through Serengeti National Park, Tanzania	
61	The role of Usangu wetlands in biodiversity, ecosystem services and socio-economical development of the people in Tanzania	Banga Paul
SUB-THEME: WILDLIFE DISEASES AND ECOSYSTEM HEALTH		
62	Malignant catarrhal fever: a field trial of a novel vaccine strategy	Felix J. Lankester, *et al.*
63	Neglected tropical diseases: One health and the role of nonhuman primates	Knauf, S. *et al*.
64	Genetic and ecological drivers of tuberculosis at human-livestock-wildlife interface of the Serengeti ecosystem, Tanzania	Bugwesa Z. Katale *et al.*
65	Free-roaming domestic dog demography and vaccination near Serengeti National Park in Tanzania	Anna Czupryna, *et al.*
66	Causes of mortality in baboons at Gombe National Park: the role of intrinsic factors, predation, disease, and conflict with humans.	A. Collins, *et al.*
67	Health and demographics of African buffalo (*Syncerus caffer*) in Ruaha National Park, Tanzania	Epaphras A. Muse, *et al.*
68	Systematic surveillance and capacity strengthening to detect emerging viral zoonoses of wildlife origin in Tanzania	Zikankuba Sijali, *et al.*
69	Free from the cold-chain? A rabies vaccine thermo-stability trial	Felix J. Lankester, *et al.*
70	Seroprevalence of tuberculosis in domesticated elk (*Cervus canadensis*) in Korea	Shin-Seok Kang, *et al.*
71	Preliminary field and laboratory observations of the effects of handling stress of natural populations of the pancake tortoise (*Malacochersus tornieri*)	Ray Shoo and Reginald Mwaya
72	Detection of arenaviruses in rodent and shrews from selected wildlife-human interfaces in Tanzania	Ruth Maganga, *et al.*
73	Sero-prevalence and spatial distribution of Rift Valley Fever in humans residing in agro-pastoral and pastoral communities during inter-epidemic period in the Serengeti ecosystem, northern Tanzania	Jabir Makame, *et al.*
BEEKEEPING, BEE ECOLOGY, BEE PRODUCTS AND POLLINATION		
74	Challenges and opportunities for sustainable	Janemary Ntalwila, and

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	beekeeping livelihoods in Miombo wooland of Mlele District western Tanzania	Angela Mwakatobe
75	Current challenges of beekeeping sector in Tanzania	Mumbi, C.T., *et al.*
NATURAL RESOURCES GOVERNANCE AND INFRASTRUCTURE		
76	Impacts of the Tanzania - Zambia tarmac road on wildlife road kills and waste in Mikumi national park	Julius Keyyu, *et al.*
77	The impact of the Tanzam highway on diet, ranging and foraging behaviour of yellow baboons in Mikumi national park	Amani Kitegile, *et al.*
78	Performance of wildlife conservation approaches in Northern Tanzania	Christian Kiffner
79	Perceptions of the Maasai inhabiting the Loliondo District of Tanzania Regarding Agencies involved in the Process of Conservation-based Land-use Planning	Steria Ndaga,*et al.*
80	Natural Resources governance in a multiple use protected area, Mlele Beekeeping Zone – Katavi Region	Napoleon Frank, *et al.*
81	Indigenous Knowledge Utilization and Land Use in Tanzania: The case of Usambara Mountains	Fadhili Bwagalilo, *et al.*
82	An overview of environmental data and data owners in the Coastal area of Tanzania-an emerging environmental spatial data infrastructure.	Christopher Muhando, *et al.*
83	Avian Flight Heights across Power lines in Dar es Salaam	Joinse Tuyishime and Jasson John
	THEME ETHNO-BOTANY AND VEGETATION ECOLOGY	
84	Drivers of tree community composition and seed demography in Serengeti.	Deusdedith Rugemalila, *et al.*
85	How to live with invasive? Positive environmental and climate mitigation effects of *Prosopis juliflora* in Ethiopian rangelands	Anna C. Treydte, *et al.*
86	Phylogenetic diversity of plant communities at Mt Kilimanjaro in relation to elevation and human impact	Neduvoto Piniel Mollel, *et al.*
87	The importance of ethno-medicinal plants amongst the Iraqw in the Karatu District: Cultural and Conservation implication	John Mwamhanga *et al.*
88	Forest edge effects for the three glade types in Mount Meru Game Reserve	*Ladislaus W. Kahana*, et al.
89	The Distribution and causes of alien plant	John Bukombe, *et al.*

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90	Projected Population Growth and Deforestation in the Serengeti Ecosystem	Aine Seitz McCarthy, *et al.*
POSTER PRESENTATION		
91	Environmental awareness and beekeeping in selected villages at Malagarasi-Muyovozi ramsar site	Jasson John, *et al.*
92	Effect of land use and elevation gradient on soil aggregate fractionation on Kilimanjaro ecosystems	Emanueli Ndossi
93	Can rhino ranching reduce its poaching in Tanzania?	Emmanuel Chacha Matiko
94	Considerations of West Usambara colobus monkeys: A documentation of conservation activities and their impacts on colobus monkeys around Magamba Nature Reserve	Mwihomeke Mickfanaka *et al.*
95	Wilderness and road networks in protected areas	Ragnvald Larsen, *et al.*
96	Mapping chimpanzee artifacts: What can they reveal about hominin evolution?	Alejandra Pascual-Garrido
97	A changing climate in the rangelands of Northern Tanzania: effects on people and their ecosystem services	Silvia L. Ceppi, *et al.*
98	Human – wildlife, interaction around selous game reserve in Tanzania	Twaha Twaibu
99	Raw material procurement for termite fishing tools in wild chimpanzees	Katarina Almeida-Warren and Alejandra Pascual-Garrido
100	Simian strains of the bacterium *T. pallidum*: A missing link to understand syphilis's evolution?	Chuma, I. S. *et al.*
101	Population health parameters in olive baboons (*Papio anubis*)	Lipende, I. F. *et al.*
102	Behavioral determinants and consequences of the natural spread of a sexually transmitted disease in wild olive baboons (*Papio anubis*)	Paciência, F. *et al.*
103	Integrating indigenous knowledge and science in wildlife management	Obeid Mahenya
104	The use of sleeping tree refuges by yellow baboons in Mikumi National Park	Samuel Mtoka and Guy W Norton
105	Can Geographical Indication labeled honey address the local pollinators decline in Tanzania?	Godfrey Nyunza

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106	Implications of land cover changes on community's livelihoods along the slopes of Mt. Kilimanjaro in the changing climate	Hawa K. Mushi
107	Soil Erosion under Different Vegetation Cover and Land-use: Experience from Cultural Landscape of Mt. Kilimanjaro, Tanzania	Jerome Kimaro, *et al.*
108	The influence of microcredit-funded businesses on human welfare and bushmeat consumption among communities in serengeti, Tanzania	Lowasssa, A., *et al.*
109	GIS platform; connecting land, people, and biodiversity	Samuel Kimani
110	Evaluating techniques to estimate lion abundance	Jerrold l. Belant, *et al.*
SEMINAR PRESENTATIONS-PAPERS		
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	A brief introduction to AfricanBioServices	Eivin Røskaft
111	Modeling how population growth affects biodiversity and ecosystem function through land use changes and infrastructure development	Bente Jessen Graae
112	Modeling effects of climate change on biodiversity and ecosystem dynamics	Joseph Ogutu
113	How biodiversity enables different ecosystem services along landscape gradients	Han Olff
114	How AfricanBioServices will contribute to establish better strategies challenges related to conservation of the Serengeti Ecosystem	William Mwakilema
115	Household welfare dependence on ecosystem services	Martin Reinhardt Nielssen
116	How AfricanBioServices will contribute to develop better strategies related to conservation of protected areas in Tanzania	Jafari Kideghesho
SEMINAR 2: IN THE SAVANNA ECOSYSTEMS		
117	Fire regimes impact tropical montane forest composition during periods of rapid climate change	Colin J. Courtney Mustaphi *et al.*
118	Modeling the interactive dynamics of grass, trees, fire and wildebeest in the Serengeti ecosystem	Andy Dobson
119	Environment, humans and scale as determinants	Gareth Hempson

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	of biodiversity patterns across Africa	
120	Savannah bird community change and fire management	Colin M Beale and Elliot Kinsey
121	Characteristics and interactions of fire in the Serengeti ecosystem	James Probert *et al.*
122	What controls seedling survival in savannas? Experimental tests of water limitation, herbivory and fire in Serengeti	Thomas A. Morrison
SEMINAR 3: WHAT HAS SCIENCE EVER DONE FOR LAW ENFORCEMENT		
123	Large mammals census methods and recent census results in Tanzania	Edward Kohi
124	Lessons learned by advanced spatial methods: how can this science help management authorities in sustainable conservation?	Colin Beale
125	Can cheaper and more frequent surveys better inform law enforcement and management? What data are worthwhile now, and what could CIMU improve upon?	Howard Frederick

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